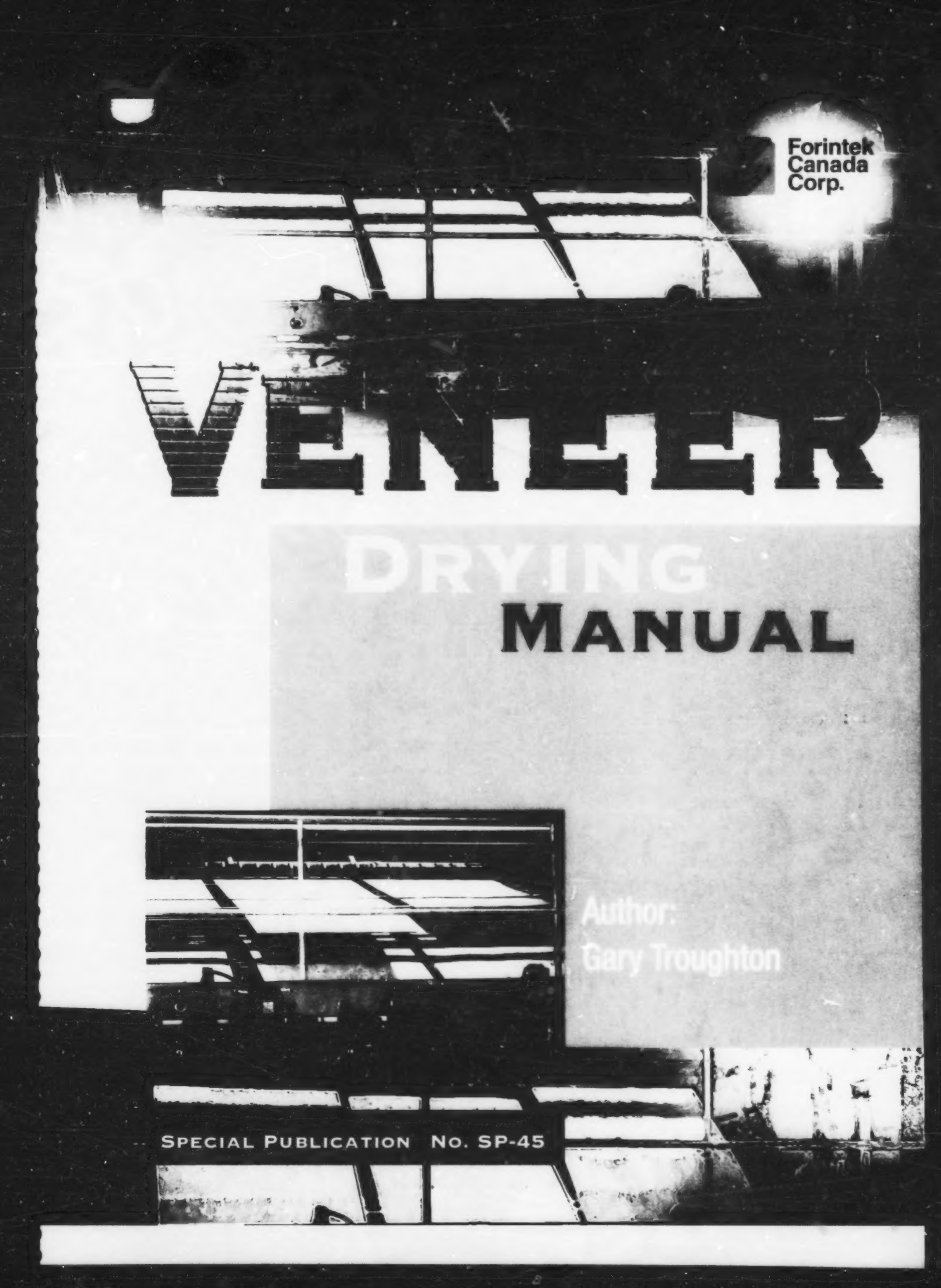
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VENEER DRYING MANUAL

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SPECIAL PUBLICATION

No. SP-45

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on whose publication this updated veneer drying manual is based.

INTRODUCTION

Since the Forintek Veneer Drying Manual was published in 1982, many new developments in veneer drying technology have been implemented in plywood and laminated veneer lumber (LVL) mills. New technologies such as veneer incising and new pollution abatement methods to control dryer emissions are now commonly used in .he plywood and LVL mills.

The purpose of the new manual is to update the1982 veneer drying manual and present new veneer drying technologies for use by dryer operators, foremen and managers. This manual is prepared for the plywood and LVL mills of both eastern (primarily hardwood veneer) and western (primarily softwood veneer) Canada.

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Right: Stain caused by water dripping (the water contained some iron in solution)

CHAPTER 1

VENEER MOISTURE CONTENT - EFFECT ON BONDING

1.1 GREEN VENEER MOISTURE CONTENT

In veneer drying, as in lumber drying, the moisture content (MC) is the amount of moisture in the wood expressed as a percentage of the oven-dry (moisture-free) weight of the wood. This percentage can be found by drying the wood in an oven set at 105°C until constant weight is achieved.

For example, if the green wood (original weight) weighs 200 grams (g) and the oven-dry wood (oven-dry weight) weighs 100 g, the amount of water evaporated is 100 g. This water represents the weight of the oven-dry (OD) wood. Therefore, the original MC was 100 per cent as shown by the following calculation:

Equation 1

$$\text{(OD method)} \quad \%\,MC = \frac{\text{original wt} - \text{OD wt.}}{\text{OD wt}} \times 100\,\%$$

upon substitution into equation 1

$$\text{(OD method)} \quad \%\,MC = \frac{200 - 100}{100} \times 100\% = 100\%$$

It is noted the OD method described above is not used for all the forest products industry. In the pulp and paper industry, the MC is based on the green weight. Thus the green MC for the above veneer sample is calculated according to Equation 2.

Equation 2

$$\text{(Green method)} \quad \%\,MC = \frac{\text{original wt} - \text{OD wt.}}{\text{original wt}} \times 100\,\%$$

upon substitution into equation 2

$$\text{(Green method)} \quad \%\,MC = \frac{200 - 100}{200} \times 100\% = 50\%$$

Every dry-end quality control person should have a drying oven to allow him to check his portable moisture meter and his continuous moisture register regularly for results. The dryer itself can be used as a drying oven to bring veneer samples to zero per cent MC. This is true for all types of dryers. The main advantage is that full sheets or, at least, half sheets (4 x 4 ft [1.2 x 1.2 m]) can be used as samples, thus giving the average MC of a large area. The main disadvantage of this method is that it does not detect wet spots.

Sheets to be oven-dried in the dryer are first weighed, and the weight is marked on the veneer. They are then passed through the dryer several times until they stop losing weight. The final figure is the OD weight. The MC is then calculated as shown above. When using large sheets, one must be careful not to lose knots or veneer pieces in the process.

1.2 MOISTURE CONTENT OF VARIOUS SPECIES

Green wood often contains large quantities of moisture. In the sapwood of some species (the outside, light-coloured wood of a log), the weight of water may be greater than the weight of the wood itself. When this is the case, the MC is higher than 100 per cent. Generally, the heartwood (the inside, often darker-coloured wood of a log) contains less moisture. In some softwoods, for instance, the MC of the heart may be as low as 30 per cent (Figure 1).

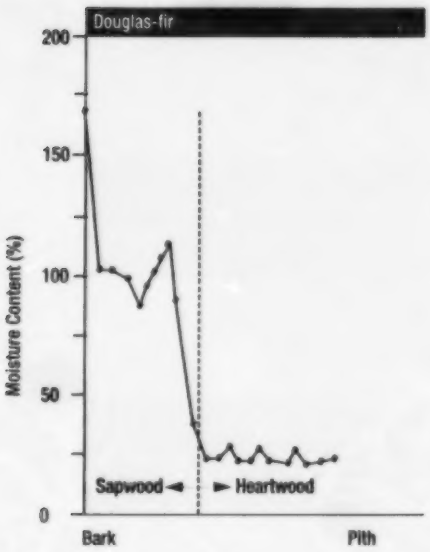

FIGURE 1

Radial moisture distribution of Douglas-fir wood from bark to pith

Table 1 (Dokken, 1972; Feihl, 1982) gives the average MC of the major Canadian species.

The MC in green veneer can vary considerably, especially in veneer sheets that contain both heartwood and sapwood. In these veneer sheets, some areas can be as low as 30 per cent MC while other areas can be over 150 per cent MC in the same veneer sheet. Veneer sheets containing both heartwood and sapwood are the most difficult to dry to a uniform MC.

Hardwoods		Average Green Moisture Content		
		Sapwood (%)	Mixed Wood (%)	Heartwood (%)
Alder, red	*Alnus rubra*	97		–
Ash, white	*Fraxinus americana*		47	
Aspen, trembling	*Populus tremuloides*	275		75
Basswood	*Tilia americana*	90		230
Beech	*Fagus grandifolia*	72		55
Birch, white	*Betula papyrifera*	72		89
Birch, yellow	*Betula alleghaniensis*	72		74
Butternut	*Juglans cinerea*		104	
Cherry, black	*Prunus serotina*	–		58
Cottonwood, black	*Populus trichocarpa*	146		162
Elm	*Ulmus*	92		95
Hickory	*Carya*	54		80
Maple, soft	*Acer rubrum*	97		58
Maple, sugar	*Acer saccharum*	72		65
Oak, red	*Quercus rubra*	69		80
Oak, white	*Quercus alba*	78		64
Walnut, black	*Juglans nigra*	73		90

Softwood		Average Green Moisture Content	
		Sapwood (%)	Heartwood (%)
Cedar, western red	*Thuja plicata*	250	58
Fir, Douglas-	*Pseudotauga mensiesii*	115	37
Fir, amabilis	*Abies amabilis*	160	98
Fir, balsam	*Abies balsamea*	195	92
Hemlock, eastern	*Tsuga canadensis*	119	97
Hemlock, w tern	*Tsuga heterophylla*	170	85
Larch, western	*Larix occidentalis*	119	54
Pine, Jack	*Pinus banksiana*	125	40
Pine, lodgepole	*Pinus contorta*	120	41
Pine, Ponderosa	*Pinus ponderosa*	148	40
Pine, red	*Pinus resinosa*	130	35
Pine, white	*Pinus strobus*	165	95
Spruce, Sitka	*Picea sitchensis*	142	41
Spruce, white	*Picea glauca*	175	55

TABLE 1

Moisture Content of Canadian Veneer Species

1.3 MOISTURE CONTENT RANGE IN DRY VENEER

There is a considerable variation in the MC of green veneer in many species. As a result, we can expect some variation in the MC of dry veneer (Dokken and Lefebvre, 1973a; 1973b). As a rule, the drier the veneer, the smaller the MC variation. The range of the final MC to be expected in veneer dried in a commercial dryer is indicated in Figure 2 (Dokken, 1972). Although these results may vary with the species and the drying conditions, the information presented in this Figure is a useful guide. It shows, for instance, that the MC of veneer dried to an average of five per cent can be expected to vary from zero to 12 per cent.

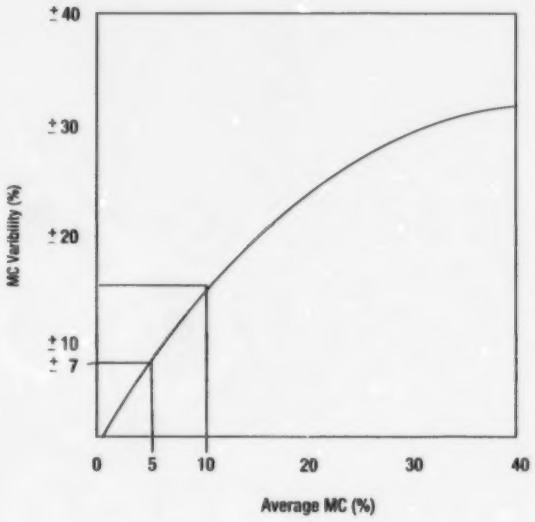

FIGURE 2

Moisture content variability as related to average moisture content. This Figure is based on studies of veneer dried in a cross-flow commercial dryer (Dokken, 1972)

Green veneer containing both sapwood and heartwood (Chow, *et al.*, 1973), is the most difficult to dry to a uniform MC. A heartwood drying schedule must be used for veneer sheets containing both sapwood and heartwood since a sapwood drying schedule (longer drying time) will result in overdried (inactivated) portions of the veneer sheet containing the heartwood. The inactivated veneer would then produce defective bonds when made into plywood.

1.4 EFFECT OF MOISTURE CONTENT ON GLUE-WOOD BOND QUALITY

For best performance with glues, the veneer should be dried to a uniform MC which is most suitable for the particular glue. Some recommended MC ranges for glues commonly used to bond plywood and laminated veneer lumber (LVL) are the following:

	MC Range
1. Hot pressing with urea formaldehyde glue (interior-type plywood)	6 to 8%
2. Hot pressing with conventional phenol formaldehyde glue (exterior-type plywood and LVL)	3 to 5%
3. Hot pressing with moisture tolerant phenolic glue (exterior-type plywood and LVL)	8 to 10%

In the 1990s, new moisture-tolerant phenolic adhesives (Steiner, *et al.*, 1993) were developed to bond veneer at higher MC levels. Several advantages are realized when bonding at higher MC such as reduced drying times and MCs of plywood closer to service conditions when coming out of the press. The higher MC in the plywood improves its dimensional stability. At the higher MC levels of eight to 10 per cent, the conventional phenol formaldehyde glues over-penetrate into the veneer and the cure is inhibited by the high levels of moisture.

For all the above glues, if the veneer is too dry (zero to one per cent MC), the water is absorbed rapidly into the veneer. This absorption is accelerated if the veneer is hot or if there are higher temperatures in the mill such as in the summer. This effect reduces the flow properties of the glue which is required for good bonding. Thus the closed assembly time is very important to control in the mill. This is the time taken to place the glued veneer assemblies into the press. If the closed assembly time is too long, then too much water is absorbed into the veneer and a defective glue-wood bond results (starved or "dried-out" glue line). Longer closed assembly times can be tolerated in winter conditions because of lower mill temperatures.

No glue formulation can compensate for veneer with wet and dry areas. If the wet areas have high MC, then not only does the glue not cure properly, but this moisture turns to steam during hot pressing and the panel will blow or blister.

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CHAPTER 2

MOISTURE METERS AND DETECTORS

2.1 PORTABLE MOISTURE METERS

There are three types of portable moisture meters (Feihl, 1982) available: (a) resistance, (b) capacitance and (c) power-loss for measuring MC in veneer up to the fibre saturation point (FSP) (25 to 30 per cent). Above the FSP, these meters are inaccurate.

(a) A resistance-type meter can be used on thick veneer. It has two pins, 5/16 inches (8 mm) long, which must be inserted into the veneer sheet (or sheets). The pins should be aligned parallel to the grain. If several sheets are piled one on another, the wettest veneer to be touched by the pins determines the MC reading. The resistance meters function on the inverse relationship between wood MC and direct-current electrical resistance. A close relationship between MC and resistance exists only between seven per cent and about 25 per cent MC.

(b) Capacitance meters make use of radio frequency (RF) and are based on the relationship between MC and dielectric constant. Dielectric constant is the ratio of the capacity of a capacitor with a piece of wood between the plates relative to the capacity of an identical capacitor with air between the plates. At frequencies between one and 16 MHz, the dielectric constant increases in a linear fashion from five to 25 per cent MC. The capacitance meters have surface-contact electrodes and hence these meters avoid the pin holes which resistant-type meters leave on the veneer.

(c) Power-loss meters also employ an RF current and are based on the measurement of the loss factor when the RF penetrates the wood being assessed. The loss factor is the ratio of power absorbed per cycle of oscillating current to the total apparent power stored during the cycle. The loss factor is linearly proportional to the MC over the range from one to 12 per cent when RFs of one to 16 MHz are used. The relationship becomes more complex at higher MCs, but it is useful up to about 25 per cent MC. These meters also have surface-contact electrodes.

ADVANTAGES AND DISADVANTAGES

The principles around which meters are designed allow them to give the MC of veneer in a few seconds. Determining this MC with an oven and a scale takes minutes. Unfortunately, as well as having individual limitations, all meters have certain common sources of possible error:

(a) Failure to properly calibrate or set a meter prior to use will result in incorrect readings, so all meters should be calibrated frequently. Calibration is discussed in section 2.3 of this chapter.

(b) Meters will give an MC reading only at the point of testing, therefore, it is possible to either hit or miss wet spots and so obtain an incorrect reading.

(c) Capacitance or power-loss meters should not be used on a pile of veneer or over the surface of any material that picks up moisture—the underlying material will influence the meter reading.

(d) Visible irregularities in wood, such as roughness, knots, pitch pockets, sap stains, or irregular grain formation, will often affect the accuracy of measurements.

2.2 Continuous Moisture Detectors

2.2.1 Dry End Detector

When drying veneer, it is essential to identify the sheets that come out too wet. Different strategies to redry this veneer to a suitable MC for bonding are then used (Chapter 6). This identification is done by a continuous moisture detector. The instrument senses moisture as the veneer passes an electrode system. If the moisture exceeds a pre-set level (the marking point), an ink spray is activated and the wet sheet is marked for redrying.

Dry end detectors have been used for many years in large rotary-cut veneer operations. However, they have not found favour in smaller mills and face-veneer mills because of their high cost and the difficulty in keeping them reliable and accurate.

There are two types of electrodes available for continuous moisture detectors. One is installed across the dry chain, the other across the outfeed tipple (Erb, 1974). The older dry chain electrode averages the moisture along the full length of the sheet, while the cross tipple electrode differentiates six-inch-long wet spots from those 12 or 24 inches long. This means that wet spots can be picked up at a selected sensitivity setting that will allow veneer with normal moisture distribution (in an acceptable range) to pass without being marked for redrying (Erb, 1971). Some mills then mark the wet spots with one ink line indicating light redry and two ink lines side by side indicating heavy redry.

2.2.2 Green End Detector

Each stage of veneer drying is critical in obtaining uniform MC in the dried veneer. The first stage, green moisture sorting, is very important. Accurate sorting will lead to more uniform MC in the dried veneer and hence, it is very important to have accurate green end moisture sensors. Some species are difficult to sort visually for MC such as hemlock, white fir, spruce and aspen poplar, Individual sheets of these species often look alike but may vary from 30 to 200 per cent in MC.

There are several methods available to measure MCs above the FSP. A microwave method (Busker, 1968) has been used for many years to measure MCs above the FSP (approximately 25 to 30 per cent) in green veneer for sorting purposes. However, this method is very sensitive to the wood's dielectric properties, and factors such as the wood mineral content greatly affects accuracy.

A new patented laser method developed by MPB Lamsor Inc. (Jamroz and Warren, 1996) was tested in mill trials in late 1998 and early 1999 to sort green veneer. This method has been used successfully in several sawmills to sort unseasoned lumber and the manufacturer is confident it will sort green veneer into MC ranges very accurately. This new laser method resulted from a spin-off of Forintek's patented preheating method (Troughton and Clarke, 1987; Clarke and Troughton, 1985) to measure MC in green veneer or unseasoned lumber. The Forintek preheating method was used successfully in ten sawmills and was licensed to Novax Industries Ltd. for measuring MC in unseasoned lumber. Because of the development of the new laser method, the preheating method was not commercialized for measuring MC in green veneer.

Green end detectors are commonly set for three sorts of sheets at different moisture levels; for example, under 50 per cent (heartwood), 50 to 100 per cent (light sapwood) and over 100 per cent (heavy sapwood).

The sorted green veneer is then conveyed through a veneer dryer for a given time-temperature schedule. The schedule will depend primarily on the MC of the veneer (heart versus sap), thickness and type of dryer (longitudinal versus jet).

2.3 Calibration and Maintenance

The calibration of moisture meters and continuous moisture detectors changes with species (by up to three per cent MC), veneer thickness and veneer temperature (by up to 10 per cent MC); in addition, the material on which the veneer rests may influence the reading (readings should be taken over a styrofoam or plexiglass plate).

When a mill purchases one of these instruments, the calibration supplied by the manufacturer should first be followed as a guide. However, this calibration should be checked with the MC results obtained by the oven-drying method on an on-going basis.

For reliable results, the moisture sensor must be properly calibrated and maintained in good working order. A moisture meter is only as good as the maintenance program established by the mill management.It is recommended that a representative of the moisture meter manufacturer come in and check all equipment once every six months.

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CHAPTER 3

VARIABLES AFFECTING VENEER DRYING

The following discussion explains the two phases of veneer drying, what happens to veneer as it dries and the main variables affecting the rate of drying.

3.1 TWO PHASES OF THE DRYING PROCESS

In a freshly felled log, the water is distributed in all fibres. As illustrated in Figure 3 (Jozsa, 1994), water will be present in the fibre cavity as well as in the fibre wall. These locations of the moisture are very important in the process of veneer drying and help explain the different drying rates in the two drying phases.

The water in the fibre cavities is denoted "free water" to distinguish from the water in the fibre walls which is known as "bound water". The bound water is attracted to the wood with stronger forces than those which hold the free water (Figure 3). When a piece of wood starts to dry, a particular fibre will lose its free water first, since this water is held by weaker forces when compared to the bound water. Generally the fibres empty before bound water starts to move out. A certain stage is reached when the fibre cavities are empty but the fibre walls are still fully saturated. This stage is called the fibre saturation point (FSP) and it is when important changes in the wood properties occur.

To visualize free water and bound water we have to conjure up a wet sponge. A wet sponge, just pulled out of a bucket of water, is analogous to fully saturated and swollen wet wood. If we squeeze the sponge, free water pours out. Now imagine squeezing out all the water from the wet sponge, by squeezing it as hard as you can. A point will be reached when no more water drips out, yet the sponge remains flexible and damp to the touch. This state, as in wood, is the FSP: the fibre cavities are emptied of free water, but the fibre walls are saturated with bound water. In contrast to free water, which is held in fibre cavities like water in a glass, the bound water is held by chemical forces of attraction within the fibre walls.

When the veneer enters the dryer, the surface moisture is evaporated almost immediately. The veneer temperature begins to increase and the free water moves to the surface where it evaporates. The evaporation is a cooling process: the veneer surface temperature is much lower than the actual air temperature within the dryer. When all the free water in the cavities has been removed, only bound water (in the fibre walls) remains, the FSP. At this moment, the veneer MC is about 25 per cent. Bound water is more difficult to remove than free water because the water is chemically bonded to the fibre walls. Therefore the drying rate, which was quite rapid before the FSP was reached, slows down considerably (Figure 4). Thus there are two phases in the veneer drying process. Phase 1 represents a fast drying rate from the initial green MC to the FSP and Phase 2 represents a much slower drying rate from the FSP down to zero per cent MC (Figure 4).

When only bound water is being evaporated and the MC is close to zero per cent, the water is already in vapour form as it reaches the veneer surface. The cooling effect of evaporation is thus lost and the veneer surface temperature begins to increase rapidly above 100°C. The veneer can attain the same temperature as that in the dryer at the dry end. Under these conditions, chemical changes occur rapidly on the surface of the veneer which will interfere with good bonding when making plywood. This phenomenon is called surface inactivation ("case hardening" in mill jargon). Specifically, at the higher veneer surface temperatures, bonding sites on the wood surface are destroyed by chemical oxidation reactions (Chow, 1975;

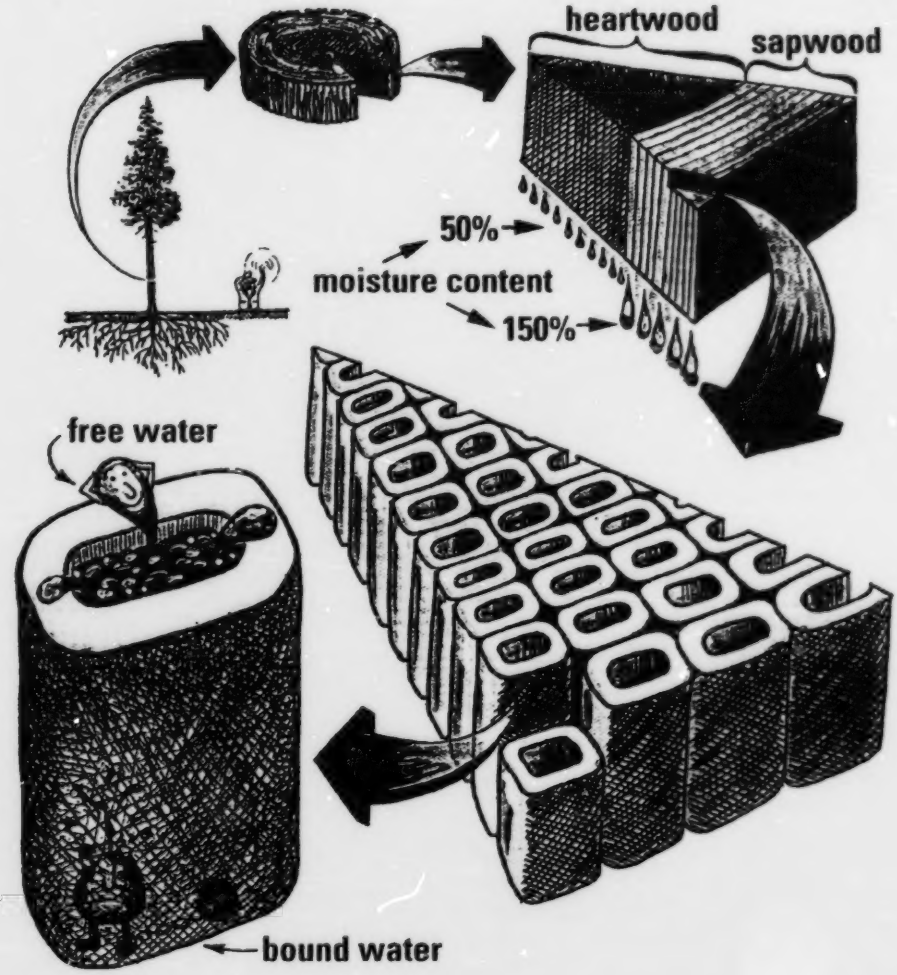


FIGURE 3
Bound and free water in wood

Troughton and Chow, 1971). Concurrently, thermal degradation reactions occur which reduce the strength of the surface wood fibre (Troughton and Rozon, 1974). Both these chemical reactions result in defective bonds caused by overdrying the veneer.

The FSP is also important in wood drying because it is the point when wood begins to shrink. No shrinkage takes place as long as the fibre walls are saturated with water. Because of this shrinkage, slightly wider green veneer sheets must therefore be used to reach the target veneer width. Thus green veneer sheets are clipped to about 54 inches in width and after drying to an average four per cent MC will shrink to about 50.5 inches. Table 2 gives the radial (thickness) and tangential (width) shrinkage for the major Canadian species. It is noted longitudinal (length) shrinkage is minimal, usually about 0.1 per cent.

FIGURE 4
Oven-drying curve at 180°C for incised 1/8 inch spruce veneer

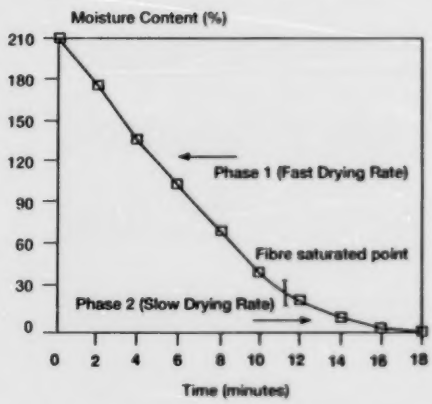


TABLE 2

Shrinkage of Canadian Veneer Species

Hardwoods		Shrinkage*			
		Green to 6% MC		Green to 0% MC	
		Radial (thickness) (%)	Tangential (width) (%)	Radial (thickness) (%)	Tangential (width) (%)
Alder, red	*Alnus rubra*	3.5	5.8	4.4	7.3
Ash, white	*Fraxinus americana*	3.8	6.2	4.8	7.8
Aspen, trembling	*Populus tremuloides*	2.8	5.4	3.6	6.6
Basswood	*Tilia americana*	5.3	7.4	6.7	9.3
Beech	*Fagus grandifolia*	4.1	8.8	5.2	11.0
Birch, white	*Betula papyrifera*	5.0	6.9	6.3	8.6
Birch, yellow	*Betula alleghaniensis*	5.8	7.4	7.2	9.2
Butternut	*Juglans cinerea*	2.7	5.1	3.4	6.4
Cherry, black	*Prunus serotina*	3.0	5.7	4.0	7.1
Cottonwood, black	*Populus trichocarpa*	3.1	7.4	3.9	9.2
Elm	*Ulmus*	3.4	7.6	4.2	9.5
Hickory	*Carya*	5.6	8.0	7.0	10.0
Maple, soft	*Acer rubrum*	3.2	6.6	4.0	8.2
Maple, sugar	*Acer saccharum*	3.9	7.6	4.9	9.5
Oak, red	*Quercus rubra*	3.2	6.6	4.0	8.2
Oak, white	*Quercus alba*	4.2	7.2	5.3	9.0
Walnut, black	*Juglans nigra*	4.4	6.2	5.5	7.8
	Softwood				
Cedar, western red	*Thuja plicata*	1.9	4.0	2.4	5.0
Fir, Douglas-	*Pseudotauga mensiesii*	4.0	6.2	5.0	7.8
Fir, amabilis	*Abies amabilis*	2.6	5.7	4.2	8.9
Fir, balsam	*Abies balsamea*	2.3	5.5	2.9	6.9
Hemlock, eastern	*Tsuga canadensis*	2.4	5.4	3.0	6.7
Hemlock, western	*Tsuga heterophylla*	3.4	6.3	4.3	7.9
Larch, western	*Larix occidentalis*	3.4	6.5	4.2	8.1
Pine, Jack	*Pinus banksiana*	3.0	5.0	4.0	5.9
Pine, lodgepole	*Pinus contorta*	3.6	5.4	4.7	6.8
Pine, Ponderosa	*Pinus ponderosa*	3.1	5.0	3.9	6.3
Pine, red	*Pinus resinosa*	3.7	5.8	4.6	7.2
Pine, white	*Pinus strobus*	1.8	4.8	2.5	6.3
Spruce, Sitka	*Picea sitchensis*	3.4	6.0	4.6	7.8
Spruce, white	*Picea glauca*	2.5	5.5	3.2	6.9

* Percentages are based on dimensions when green.

3.2 VARIABLES AFFECTING DRYING TIME

There are many variables which affect the time required to dry veneer and they can be divided into three categories (Comstok, 1971): (1) equipment variables, (2) process variables, and (3) veneer sheet variables. Equipment variables include such features as jet nozzle or orifice design (size and shape), per cent orifice area, etc.

Process variables include temperature, air velocity, relative humidity of air in the dryer, and the agent which conducts the heat to the veneer. Thirdly, veneer sheet variables include density, veneer thickness and MC.

The equipment variables such as jet nozzle design are set by the equipment manufacturer and therefore will not be discussed further. The effect of the process and veneer sheet variables on drying rate are now discussed.

(a) Effect of veneer thickness on drying time.

As expected, drying time increases with veneer thickness. Results obtained with softwood and hardwood veneers dried in a cross-flowdryer at Forintek Canada Corp.'s Eastern Laboratory, indicate that the drying time increases approximately in direct ratio to veneer thickness (i.e., if the thickness is doubled, so is the drying time) (Dokken, 1972; Feihl, 1962). The linear relationship between veneer thickness and drying time is shown in Figure 5a.

(b) Effect of moisture content on drying time

Figure 5b illustrates that drying time increases with increasing MC and that is why much longer drying schedules are required for sapwood veneer than heartwood veneer. For many softwood species, the MC range is very large, making it important to sort the veneer. For example, for white spruce, the MC for sapwood ranges from 90 to 260 per cent for sapwood and 10 to 100 per cent for heartwood. However, many hardwood species such as yellow birch or hard maple have a more even MC and show little difference in MC between heartwood and sapwood; therefore, only one drying schedule is used for both types of veneer.

(c) Effect of drying temperature on drying time

Temperature has a marked effect on drying time (Figure 5c) (Dokken, 1972; 1975). For example, if it takes 10 minutes to dry veneer at 300°F (149°C), it takes half that time at 410°F (210°C) and only one-quarter of that time at 600°F (310°C). Most dryers today operate at temperatures ranging from about 300°F (149°C) in steam-heated dryers to 500°F (260°C) in gas-heated dryers. However, high temperatures such as 500°F (260°C) employed in jet dryers are only used in the green end where the MC of the veneer is high and lower temperatures are used in the dry end of the dryer. Higher veneer dryer temperatures will accelerate veneer surface inactivation as discussed in Section 3.1

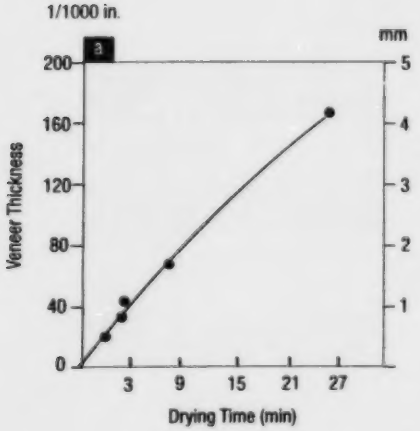
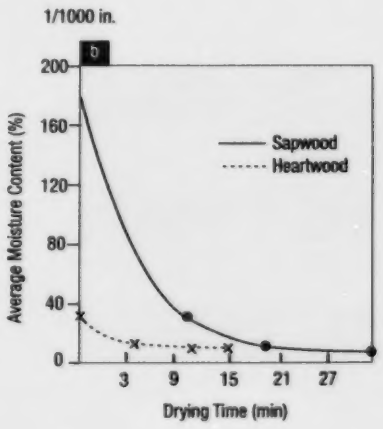


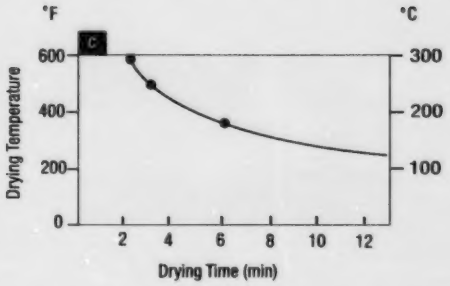
FIGURE 5A

Effect of veneer thickness on drying time

FIGURE 5B

Effect of moisture content on drying time. (heart vs. sap)





Relevent information

Figure	Species	Thickness		Temp		Dryer Type
		in.	mm	°F	°C	
5a	Yellow birch	-	-	300	149	cross-flow
5b	White spruce	1/10	2.5	300	149	cross-flow
5c	Various species	-	-			cross-flow
5d	Beech	-	-			experimental

FIGURE 5C

Effect of temperature on drying time.

(d) Effect of air speed on drying time

The faster the air flows on the veneer surface, the faster the veneer dries. The drying time is three times shorter when the air speed (velocity) increases from 240 to 1,600 ft/min (70 to 480 m/min) (Keylwerth, 1953) (Figure 5d). Prior to 1960, the air circulation in most mechanical veneer dryers was either in the longitudinal direction of the dryer or across the width of the dryer. Typical air velocities in such dryers, measured 1/4 inch (6 mm) above the veneer surface, were about 600 to 900 ft/min (180 to 270 m/min). Higher velocities are not used in these dryers because the power consumption of a fan increases with the cube of air velocity (i.e., if you want to double the air velocity, you have to use 2 x 2 x 2 = 8 times more power). If the fan speed must be increased, the fan manufacturer should be consulted since maximum fan speeds are critical and must not be exceeded.

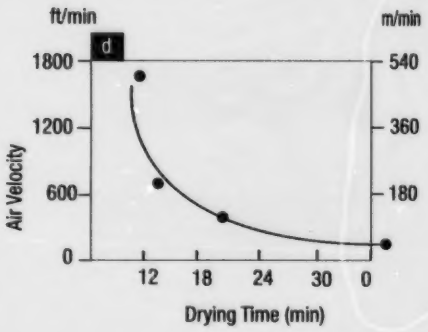


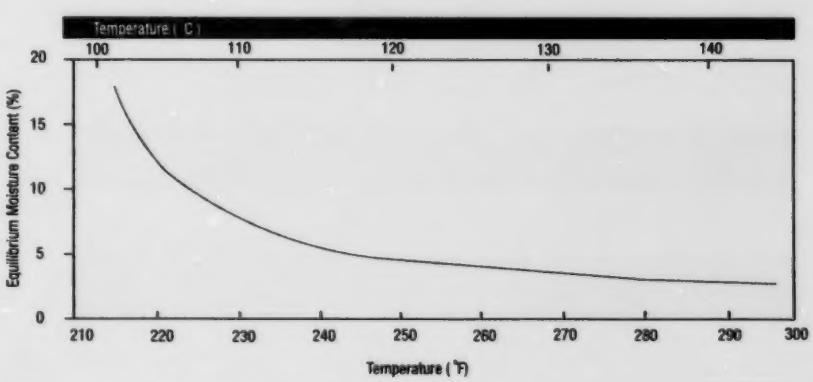
FIGURE 5D

Effect of air velocity on drying time:

To resolve this difficulty, most veneer dryers manufactured after1960, jet dryers, have the air impinging directly onto the face and back of veneer through slots or orifices. The air velocity is in the range of 2,000 to 10,000 ft/min (600 to 3,000 m/min). The fast moving air jets, hitting the veneer surface at right angles, tend to break up any boundary layer at the sheet surface, and greatly improve heat transfer (Lutz, 1978). The boundary layer is a film of slowly moving, saturated air on the veneer surface. This layer has a strong influence on the rate of moisture evaporation from the wood. It is essential to remove moisture from this layer as rapidly as possible to maintain the desired drying rate. Results at the Eastern Forintek Laboratory showed that 0.9 mm white oak face veneer can be dried twice as fast in a jet dryer than in a cross-flow dryer.

FIGURE 6

Equilibrium moisture content of wood in saturated steam at atmospheric pressure (Grummach, 1951)



e) Effect of air humidity on drying time

Since the air in the dryer absorbs the moisture that evaporated from the veneer, can this hot, moist air still dry the veneer efficiently? The answer is yes. Experiments have shown that even superheated steam (at atmospheric pressure) dries veneer quite well (Laity, et al., 1974). If veneer is left to dry in a chamber filled with nothing but superheated steam at 300°F (149°C) or higher, its final moisture content will be around two per cent (Figure 6).

(f) Influence of heat-conducting medium on drying time

Figures 4, 7 and 8 (Troughton, 1989a) show the effect of air oven drying, presss drying and steam-press drying respectively. Of these three heating mediums, steam transfers the heat the fastest, followed by press heating whereby the heat is conducted through the veneer by the heated platens and finally air oven heating whereby the heat is transferred to the veneer by convection. Thus the steam-press heating is twice as fast as the press heating and over ten times faster than the air oven drying. For the press drying, a low pressure of 25 psi or lower is required otherwise the veneer is compressed too much. Figures 7 and 8 show that at the higher platen pressures such as 200 psi, the veneer is dried at a much faster rate and the drying rate is twice as fast as the 25 psi platen pressure both for press drying and steam-press drying.

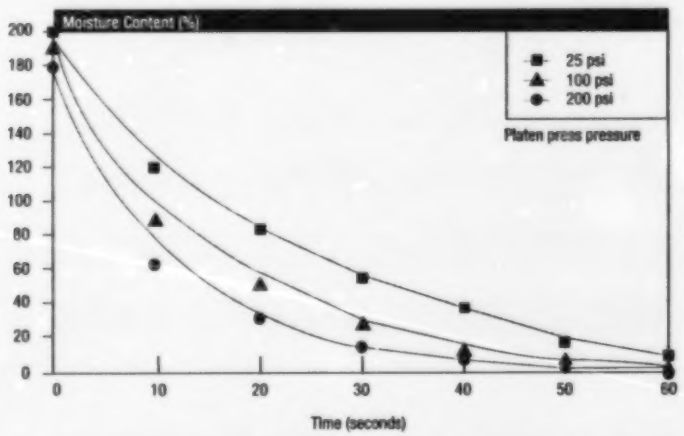


FIGURE 7

Steam-press drying curves for 1/8 inch incised spruce veneer

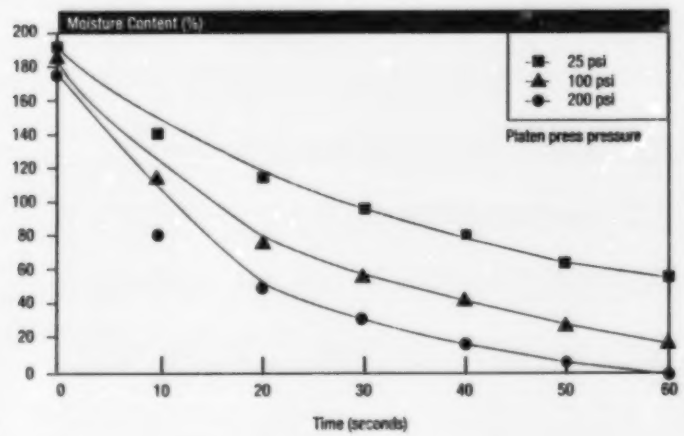


FIGURE 8

Press drying curves for 1/8 inch incised spruce veneer

Besides the much faster rates, other advantages of press drying and steam-press drying over conventional air oven drying are a significant reduction in per cent tangential shrinkage for the softwood veneers and much flatter veneer. Veneer flatness is very important for automated lay-up lines for maintaining maximum productivity. At 25 psi platen pressure, the per cent tangential shrinkage for steam-press dried white spruce veneer was reduced from seven per cent (air oven drying) to two per cent.

Because the veneers dried using 200 psi platen pressure are greatly compressed and densified, these veneers have greatly enhanced bending properties. For example, the bending strength (modulus of rupture) of steam-pressed white spruce veneer is increased by a factor of over two and the bending stiffness (modulus of elasticity) is increased by a factor of over three. (Troughton, et al., 1989b)

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CHAPTER 4 VENEER DRYERS

4.1 AIR-CIRCULATION DRYER TYPES

Three common types of air-circulation veneer dryers (Troughton, 1999) used in the plywood industry are the following: longitudinal (one and two zones), cross-flow and jet (Figure 9). All three dryer types have a cooling section to allow the veneer to be handled quickly in the next step, the gluing process. These dryers conduct heat to the veneer by means of air (heaters heat the air which in turn, heats the veneer).

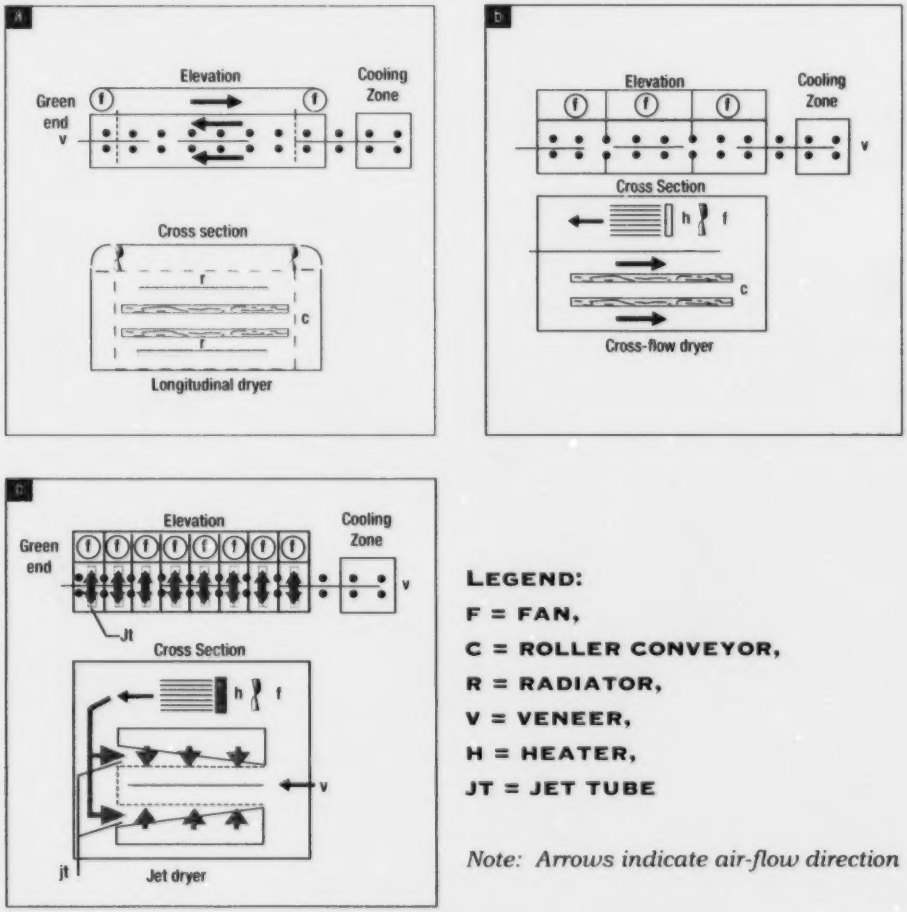

FIGURE 9

Schematic views of three types of air-circulation dryers.

LEGEND:

F = FAN,
C = ROLLER CONVEYOR,
R = RADIATOR,
V = VENEER,
H = HEATER,
JT = JET TUBE

Note: Arrows indicate air-flow direction

(a) Longitudinal Dryer

In these types of dryers, the first generation of air-circulation dryers, the air circulates along the length of the dryer. The fans (centrifugal) are generally located at the exhaust end of a zone. In large single-zone dryers, there is a set of booster fans midway down the dryer to increase air velocity. In the one-zone longitudinal dryer, the dryer temperature is higher at the dry-end, 180°C, than the green-end, 110°C. This is really opposite to the ideal situation since the green veneer can easily withstand much higher temperature than the 110°C for faster drying. Further, the 180°C at the dry-end should be lower since inactivation of the veneer surface occurs rapidly at this temperature. The two-zone longitudinal dryer is a little better since the temperature can now be controlled in two zones and provide a higher temperature at the green-end, typically 150°C and a slightly lower temperature at the dry-end, 140°C.

(b) Cross-flow Dryer

Cross-flow dryers, the second generation of air-circulation dryers were designed to greatly improve the airflow. The dryers are divided into short zones (about 10 feet long), each zone having its own fan and source of heat. The airflow direction alternates from one zone to the next. The air speeds are typically 600 to 900 ft/min measured above the veneer surface. Although faster drying rates could be achieved by higher air velocities in these dryers, this is not practical since the power consumption of the fan increases with the cube of air velocity. Because these dryers have many more temperature-controlled zones than the longitudinal dryers, they can be set such that near the green-end of the dryer, high temperatures, above 180°C, can be used whereas near the dry-end, much lower temperatures around 120°C can be used. Hence, because of the higher temperature at the green-end, faster drying rates can be achieved and there is less chance for inactivation occurring at the dry-end compared to the longitudinal dryers.

Figure 10 shows a typical cross-flow veneer dryer. Green veneer, if fed from the left (top drawing) on four decks of roller conveyors, passes through a cleaning section (optional) which removes loose knots and debris, then enters a series of drying zones (each with its own temperature control). Steam produced by the evaporation of veneer moisture escapes through the vent stacks. After progressing through all drying zones (up to 50 in some dryers), the dry, and hot sheets go through a cooling zone before reaching the outfeed unit. Unless veneer is reasonably close to room temperature when the glue is spread, there is serious danger of pre-cure in the hot press.

The bottom drawing of Figure 10 shows how air is heated and circulated in each section.

(c) Jet Dryer

Jet dryers, the third generation of air-circulation dryers, allow the hot air to impinge directly (Comstock, 1971) onto the face and back of veneer through slots or orifices at much higher air velocities than cross-flow or longitudinal dryers. The air velocities are in the range of 2,000 to 10,000 ft/min. These much faster air velocities in the jet dryer account for the much faster drying rates than the longitudinal and cross-flow dryers. The fast moving air jets hitting the veneer surface at right angles tend to break up any boundary layer at the sheet surface, and greatly improve heat transfer compared to the first and second generation type of dryers. The boundary layer is a film of slowly moving saturated air on the veneer surface. This layer has a strong influence on the rate of water evaporating from the wood. Some studies (Comstock, 1971) have shown that veneer can be dried two to three times faster in a jet dryer than in a cross-flow dryer. Because the jet dryer has several temperature-controlled zones, high temperatures up to 260°C are used

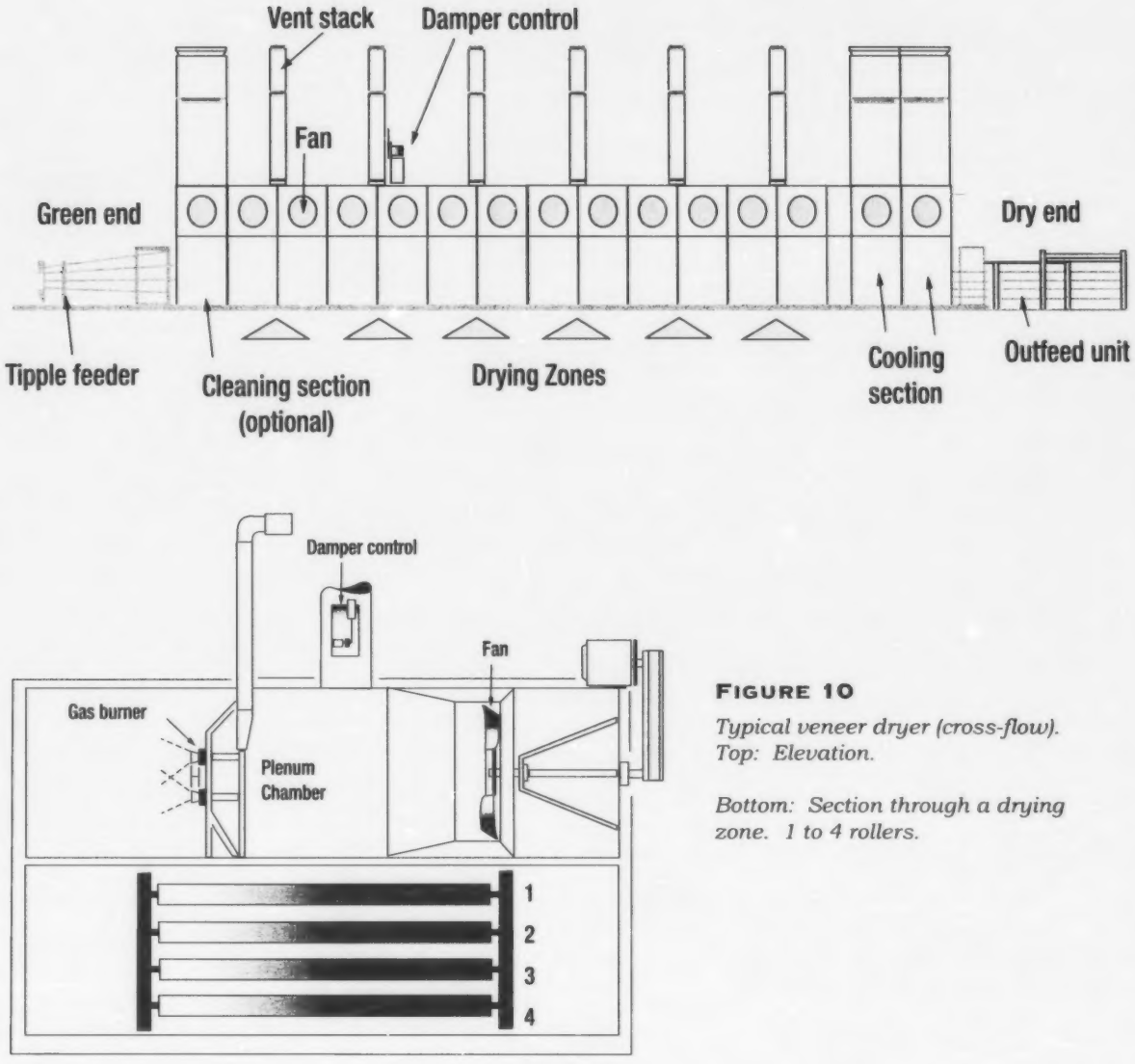

FIGURE 10

Typical veneer dryer (cross-flow). Top: Elevation.

Bottom: Section through a drying zone. 1 to 4 rollers.

in the green-end of the dryer and much lower temperature-controlled zones, 110°C to 150°C, are used in the dry-end. The reduction in dryer temperature towards the dry-end helps prevent surface inactivation of the veneer.

4.2 HEATING SYSTEMS

Veneer dryers operate within a temperature range of about 250 to 500°F (121 to 260°C). The first dryers were heated with steam radiators, their maximum temperature was only 325 to 350°F (163 to 177°C). Then came oil burners which fired directly into the plenum chamber and boosted the temperature up to 500°F (260°C). These were replaced by gas burners which are much in use today. In some cases, wood waste (particularly sander dust) was used quite efficiently in suspension burners.

(a) Steam Radiators

Since most mills have their own steam plant, it is logical to heat dryers with high-pressure steam. However, steam heating presents certain disadvantages: first, the maximum temperature obtainable in steam-heated dryers is about 350°F (177°C); second, steam pressure (hence dryer temperature) often varies from day to day and within a single day. Incidentally, this steam-pressure variation is a well-known source of trouble in veneer log heating since steam is also the heating medium for log vats and steam chambers. Table 3 shows the temperature of saturated steam at various pressures.

TABLE 3

Temperature of Saturated Steam at Various Pressures

Imperial System		SI System	
Steam Temperature (°F)	**Gauge Pressure (psig)**	**Steam Temperature (°C)**	**Gauge Pressure (kPa)**
212	0	100	101
250	310	126	308
300	53	150	467
350	121	171	936
400	233	200	1707

(b) Oil Burners

As was seen in Figure 5, the drying time can be decreased by increasing the dryer's temperature. For instance, the drying time can be cut in half by boosting the temperature from 300 to 450°F (149 to 232°C). One way to obtain this temperature in dryers is to replace the steam-heating system with oil burners. This was done around 1950 in the softwood plywood mills of the West Coast but, unfortunately, a new problem soon developed—that of bonding. It was found that veneer heated at or above 450°F (232°C) gave panels which, when their bond was tested by the plywood shear method, showed a rather low percentage of wood failure (too much of the failure happening in the glue line). After extensive research (Chow, 1975; Troughton and Chow, 1971), it was discovered that the veneer surface does not glue properly if it is allowed to become too hot in the dryer. This damage of the veneer surface, called surface inactivation, is discussed in Chapter 3. Because of the danger of surface inactivation, the drying of veneer in direct-fired oil burners was generally done at temperatures not exceeding 400°F (204°C). Another important factor with oil burners was that bad combustion leaves an oily deposit on the veneer surface causing bonding problems.

(c) Gas Burners

Oil burners did not remain long on the market; they were replaced by gas burners which are cleaner and require less maintenance. Gas burners use natural gas supplied through pipelines. Both types of burners are fired directly in the plenum chambers, and the products of combustion mix with the hot atmosphere of the dryer. This does not cause any problem provided that proper combustion conditions are maintained as was found for oil burners.

(d) Suspension Burners

The suspension burner has supplied a way of disposing of sander dust. The sander dust is blown into a combustion chamber with the combustion air and is burned while suspended. Wood waste other than sander dust may be used as fuel for this type of burner provided it is first dried and ground to less than 1/8 inch (3 mm) in size. The particle size must be small enough to not fall out of suspension during the burning process. Since there are no grates in this system, all burning must take place in the air, in suspension. This provides a means of eliminating the sander dust and generates a considerable amount of heat. In the application to veneer dryers, the exhaust from the dryer or a portion of the air circulating within the dryer is ducted to the suspension burner and injected into the blend air box beyond the sander dust burner port. There is still considerable heat content in the combined exhaust stream and it can be split with a portion being ducted back to the dryer to supply all or a portion of the heat required for the drying of the veneer (Baardson, 1974; Erb, 1971).

(e) Heat Recovery System

Because of the rising cost of energy, some mills installed heat recovery systems (heat exchangers) on the vent stacks of their veneer dryers. A study of a typical dryer (Kent, et al., 1981) has shown that a heat exchanger can recover about 20 per cent of the energy required for drying and, therefore, can pay for itself within a year.

4.3 CONVEYOR TYPES

There are two types of conveyors to forward the sheets through the drying zones (Figure 11):

(a) Endless belts, consisting of wire links, spiral coils or woven mesh.

This conveyor is used mainly for narrow faces sliced or cut on a stay log. The sheets must be kept (and therefore fed) in the same sequence in which they are produced, and are placed perpendicular to the advance of the conveyor. The endless belt is also used in in-line dryers where rotary-cut veneer often is fed directly from the reels which take up the veneer as it comes from the lathe. These conveyors are reported to work most satisfactorily with a restraint weight of about two to five pounds per square foot (10 to 24 kg/m^2) when drying thin faces (Lutz, 1978). The metal used should be a special stainless alloy that will not discolour the green veneer during drying.

(b) Pairs of rollers, the lower driven and the upper providing the pressure needed to carry the veneer forward and, at the same time, to keep it reasonably flat.

This conveyor uses pairs of rollers instead of wire belts and is designed for endwise feeding of the veneer. The lower roller is driven and the upper one simply rolls on it (or on the veneer) while applying enough pressure to control buckling of the veneer sheets.

Most dryers have several lines of conveyors on top of one another called multiple-deck dryers. Dryers with five or more decks are often seen in large mills. In some dryers, called dual-speed dryers, some of the conveyors can move faster than the others; this is useful when drying two veneer thicknesses at the same time, since the thinner veneer must be passed faster.

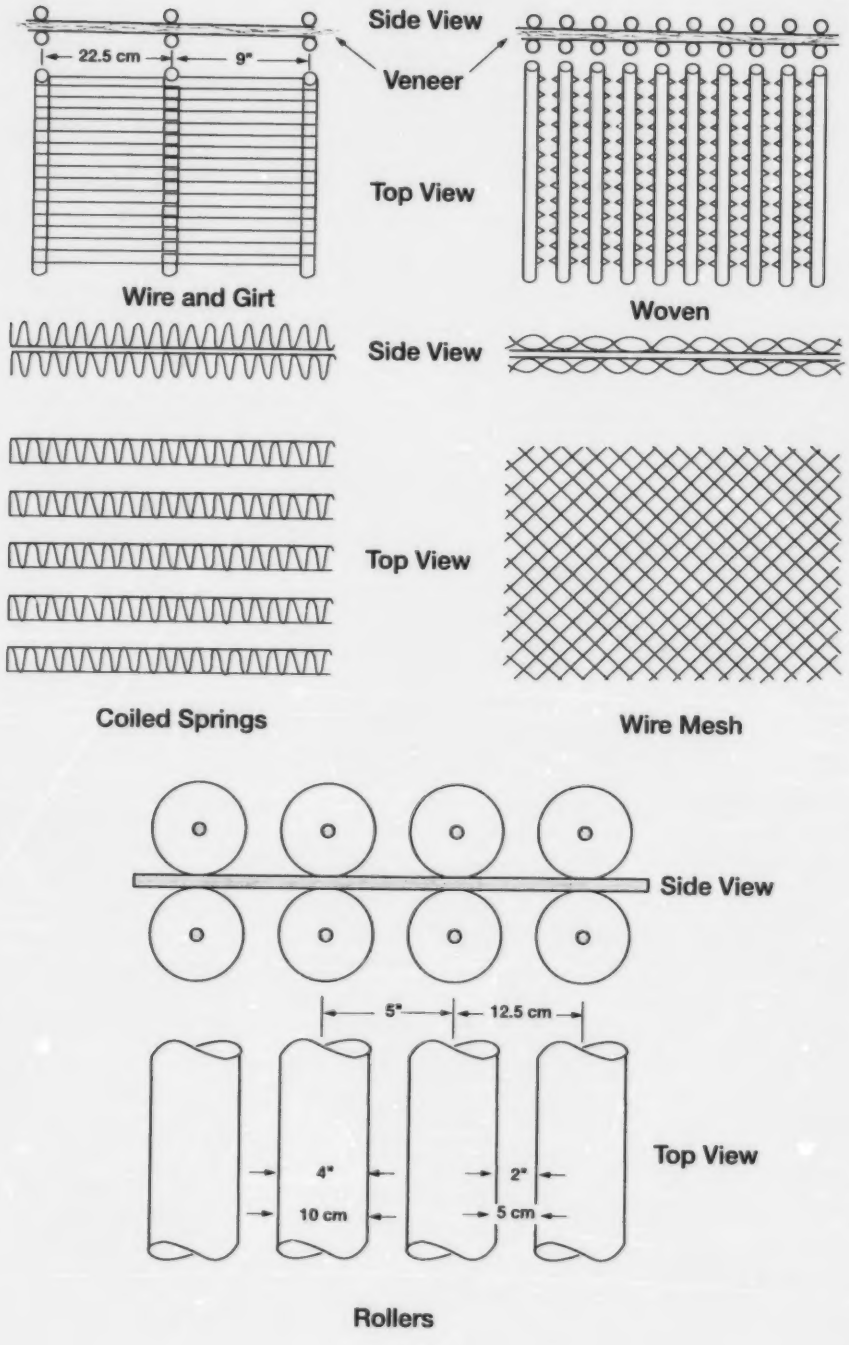

FIGURE 11

Conveyor types for veneer dryers (with approximate dimensions)

4.4 CONTROLS

A discussion on the different types of controls (manual and automated) follows:

Note: A control of secondary importance (as far as the speed of drying is concerned) is the relative opening of the stack dampers.

(a) Temperature Controls

One-zone longitudinal dryers have one temperature set for the whole length since the same air circulates from one end to the other. Two-zone longitudinal dryers, cross-flow dryers and jet dryers have a temperature control in each zone. In order to accelerate drying, the green zones in direct-fired dryers can be set at a temperature higher by 50 to 100°F (30 to 60°C), and even more, than the temperature of the dry zones. Too high a temperature in these last zones can overheat the surface of the nearly dry veneer and cause surface inactivation. This is why the one-zone longitudinal dryers are at a disadvantage since the temperature is higher at the dry end than at the green end unlike the two-zone longitudinal, cross-flow and jet dryers. This makes it difficult to control overdrying (surface inactivation) of veneer in one-zone longitudinal dryers.

An automated temperature control process (Robinson, 1987) currently being used in several U.S. and Canadian plywood mills is based on the premise that as hot air is passed over green veneer, delta T, is incorporated into a microcomputer-based control system. Details are given in Chapter 6, Section 9.

(b) Drying Time Control

Dryer conveyors are run by a variable speed drive. This allows manual (and gradual) adjustment of the drying time from about one minute to an hour. As stated before, dual-speed dryers have two independent motors so that sheets of two different thicknesses or MCs can be dried at the same time on different decks.

(c) Stack Damper Control

Several drying studies (Corder, 1963, 1976; Erb, 1971) have been made on the setting of the dampers in the vent stacks of the veneer dryers. By closing the dampers as far as possible, the humidity in the dryer is greatly increased which will result in faster drying rates for two reasons. Firstly, less heat is lost from the dryer and the average temperature throughout the dryer will be higher. Secondly, wet air transfers heat faster than dry air. Further advantages of maintaining a high humidity in the veneer dryer are more even MC, lower energy costs, less chance of surface inactivation and less chance of dryer fires. It is interesting to note that veneer will dry to a low MC in saturated steam and at 325°F (163°C), the equilibrium MC of wood in saturated steam is one per cent. It is important that all seals in the dryer are in proper order, otherwise faulty seals will result in air leaks and smoke will be emitted into the plant.

Higher humidity conditions in the veneer dryer result in a lower oxygen content and thus reduce the chances of dryer fires (Bramhall, 1967). Because of the lower oxygen content, the proper adjustment of the gas-air mixture is important in a gas-fired dryer, otherwise the flame could lose heat or go out completely.

(d) Automatic Controls

In many dryers, several controls are now automatic and the details of these automated control systems are discussed in Chapter 6, Section 9.

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CHAPTER 5

CHECKING THE DRYERS

Indications given on the dryer by information sheets, by the instruments of the control panel, or by moisture meters or detectors, may not necessarily be accurate (Feihl, 1982). That is:

1. the temperature within the dryer may not correspond throughout to that indicated on the temperature recorder;
2. the air flow may not be even through all the decks;
3. the conveyor speed may not be regular and may not correspond to the one shown on the drying time dial; and,
4. the portable moisture meters and the moisture detectors may not be well calibrated.

These points are discussed below.

5.1 Checking the Temperature

A good method (Chow, et al., 1973) to check drying temperatures in a veneer dryer is by using a heat-sensitive temperature indicator called a "Temp-plate." Temp-plates come in different sizes, shapes and temperature-range selections. A good example of a Temp-plate for veneer dryers is 3/8" x 1-1/8" in size, with four temperature indicators ranging from 350°F in 10°F increments. This Temp-plate has an adhesive backing which is pressed on the surface of the test sheet of veneer. To ensure the Temp-plates are adequately secured to veneer sheets, they are also stapled to a sheet. A sheet is passed through a dryer and the Temp-plate gives the maximum temperature reached on the veneer surface by blackening out of white-coloured temperature increments. Differences in roller temperature and air temperature in a dryer can be compared by placing a Temp-plate between two narrow, short strips of veneer stapled on a test sheet of veneer so that dryer rollers do not touch Temp-plates. It should be noted that a recorder on a dryer measures air temperatures only.

Many dryers are found to have circulation problems; i.e., large temperature differences up to 50°F (about 20°C) or more between upper and lower trays, as well as between right and left sides. These variations can be measured either by means of Temp-plates or thermocouples and corrective action taken. In many cases, leaky dryer doors drawing in cold air are the problem. Thermocouples work on the principle that two wires of different metals in contact create an electrical current which is directly related to their temperature.

Hand-held infrared temperature sensors and thermocouples are most useful and should be found in every veneer and plywood mill. They can measure the temperature of a log-heating vat or steam chamber, a dryer, a steam radiator, or a plywood press (open or closed). Since many thermocouples can be connected to the meter through a multiple switch, many temperature readings can be taken in a few seconds just by turning this switch.

5.2 Checking the Air Flow

As was seen in Chapter 3, Section 2, the speed of air has a marked effect on the drying rate. It is not uncommon, especially in old dryers that may have lost a few air-flow baffles, to find that some conveyor decks get better air circulation than others. When a dryer operator suspects that this is the case, he can check the air velocity of his dryer with an anemometer. Once he knows which spots have poor circulation, he can correct the situation (at least partially) by installing new baffles or removing those which are at the wrong place. As an example, air-velocity tests on the one-deck cross-flow dryer of the Eastern Forintek Laboratory have given the following average results:

1. without baffles – 1,013 feet/minute above veneer, 439 feet/minute below;
2. with baffles – 903 feet/minute above veneer, 1,074 feet/minute below: a much more even flow.

In jet dryers, clogged or deformed jet openings also cause uneven air flow. However, most dryers are built to permit easy removal of the jet tubes for inspection, cleaning and repair.

When centrifugal fans are being used, it is important that their cone be centred and extended at least one inch (2.5 cm) into the fan throat. Misalignment can decrease the fan efficiency by 25 per cent or more.

5.3 Checking the Conveyor Speed

How long does it take a veneer sheet to cross the dryer? For a quick answer, determine how long it takes the veneer to move 10 feet, then multiply this amount by the length of the drying zones (not the cooling zone) and divide by 10. Example: if it takes 80 seconds to move 10 feet and if the drying zones total 50 feet, then the drying time is:

Equation $$\frac{80 \text{ seconds} \times 50}{10} = 400 \text{ seconds}$$

Once you have determined this length of time, check to see if it is what your conveyor dial indicates. Do that for the range of drying times used in your mill. Moreover, check to see if your conveyor keeps a regular pace; sometimes it does not and may, for instance, vary from 18 to 23 minutes per pass. If this is so, you know that your conveyor drive mechanism needs to be checked.

5.4 Checking the Moisture Meter and the Continuous Moisture Detector

In preceding chapters it was noted that moisture meters and continuous moisture detectors are not very precise instruments; moreover, they can get out of calibration. Consequently, they must be checked regularly against the MC determined by the oven-dry method. These instruments and their calibration are described in Chapter 2.

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CHAPTER 6

OPERATING AN AIR-CIRCULATION VENEER DRYER

The operation of air-circulation dryers is very important since veneer drying can be a major cause of bond quality problems such as blows that develop through plywood formation in the pressing stage. Overdrying (which causes surface inactivation, a loss of bonding sites) and underdrying (which leads to blows during plywood formation) of veneers which may occur during the drying cycle will have a serious effect on bond quality. Not only will the overdried veneers lead to poor bond quality and delamination, but these veneers are brittle and can lead to large yield losses due to breakage.

All air-circulation dryers operate on similar principles and have the same function, that is, to dry veneer to a reasonably even final MC. This chapter discusses the various operations involved in drying veneer with this type of dryer.

6.1 GREEN VENEER SORTING

In general the MC of green veneer is highly variable and is higher in the sapwood than in the heartwood for softwood species but can be reversed for some hardwood species such as basswood (Table 1, Chapter 1). In many hardwood species such as yellow birch or sugar maple, the difference in average green moisture content between both types of wood is small (about 10 to 20 per cent); therefore, sapwood and heartwood are dried together on the same schedule. In softwood species, this difference is considerable (around 200 per cent in western red cedar), therefore, it is impossible to dry the sapwood with heartwood; they must be sorted separately, with the sapwood schedule being about twice as long as that of the heartwood.

Sorting is advantageous when a distinct difference in colour is observed between the high and low MC portions of veneer, and when the portions represent a significant fraction of the veneer to be dried. Green sorting is common practice in the Douglas-fir industry where the sheets are often separated into three piles:

1. heartwood with an average MC of 50 per cent or less;
2. mixed sap and heart sheets with an average MC of between 50 and 100 per cent; and
3. sapwood with an average MC of above 100 per cent.

Pile 1 represents about 50 per cent of the sheets; pile 2, 35 per cent; and pile 3, 15 per cent.

As discussed in Chapter 1, the drying of veneer sheets containing both sapwood and heartwood, pile 2, are the most difficult to dry to an even MC because of the wide variation of MC within the veneer sheet (can range from 40 to 200 per cent). To prevent overdrying, a heartwood drying schedule is used for this sort.

Sorting can be done manually, but more commonly is done mechanically with stackers combined with a three-level moisture meter and a memory unit which pile the green sheets into three different bins (Forest Industries, 1975).

6.2 Feeding the Dryer

This operation can be done manually or again more commonly with automatic feeders. These machines pick up the sheets from a series of veneer packages and feed them to multi-deck dryers. Their speed, of course, is synchronized with that of the dryer conveyor.

It is important that the dryer be kept full, not only because production is lost when space is left between sheets, but also because empty spaces disrupt temperature balance and heating control (Erb, 1974).

6.3 Setting the Temperature

In most mills veneer is produced faster than it can be dried—the bottleneck of the plywood manufacturing process; therefore, dryers are set for maximum output. The easiest way to obtain that is by raising the drying temperature. Unfortunately, if the veneer surface is allowed to become too hot for too long, chemical changes (oxidation and thermal degradation) develop on the surface fibres which make good adhesion difficult. This damage, called surface inactivation was discussed in Chapter 3.

The maximum safe temperature of the dryer towards the dry end (as far as preventing surface inactivation is concerned) is about 356°F (180°C). Towards the green end, temperatures as high as 500°F (260°C) are often used for both softwood and hardwood veneers. As an example, a southern pine plywood mill uses the following schedule for 1/8 inch (3 mm) veneer dried on a jet dryer (Walters, 1973).

Dryer	Number of 6-ft (1.8 m)	Temperature		Time in Zone
Zone	Sections	(°F)	(°C)	(min)
1	4	530	277	2.0
2	5	370	188	3.0
3	9	360	182	4.5
Total	18			9.5

The intent of the above paragraphs is to warn the dryer operator that he cannot boost the temperature of his machine as much as he wishes. If he does, he will dry veneer faster than his competitors but, in so doing, he will risk overdrying his veneer surface resulting in surface inactivation. The temperature of 356°F (180°C) given here as safe must not be taken as an absolute scientific limit but is offered merely as a guide, and a warning. Surface inactivation is a time-temperature phenomenon. Even at lower temperatures of 120°C, surface inactivation can be caused but only after long drying times (Troughton and Chow, 1971). The damage to the bonding sites occurs when the veneer reaches close to zero per cent MC. An indication that the veneer has been overdried is a substantial reduction below the 80 per cent average wood failure requirement in the CSA O151 plywood standard.

6.4 Setting the Drying Time

Let us assume that a dryer operator has two dryers: a 10-zone steam-heated dryer set at 325°F (163°C) in all zones, and a 10-zone gas-fired jet dryer set at 500°F (260°C) in zones 1 and 2, 400°F (204°C) in zones 3 to 5, and 350°F (177°C) in zones 6 to 10. How long should the drying time be in each dryer for a sapwood sort in order to obtain veneer with an average MC of, say, four per cent?

Two methods are used to determine the drying time experimentally, depending on whether or not the dryer is equipped with a continuous moisture detector.

(a) Dryer With Continuous Moisture Detector

This detector, installed at the dry end, marks with ink any wet spot of a certain size which passes under it. The marked sheet has to be redried. If the drying time is much too short, all the sheets will be marked for redrying; if much too long, all the sheets will be too dry for proper gluing. So a point must be reached where a good proportion of the sheets will be properly dried. When the optimum time is determined for the sapwood sort (say 15 minutes for the steam-heated dryer and 10 minutes for the jet gas-fired dryer), drying will still produce some sheets containing wet spots that will have to be redried. If the redry rate is five per cent (i.e., five per cent of the sheets passing through the dryer need redrying) it might be found that, with such a low redry rate, much of the veneer is too dry. The mill will then have to accept a reduction in the drying time by, say, two minutes in both dryers. This would increase the average MC as well as the redry rate which could jump to 10 per cent or even more (Figure 12). But the new average moisture in the veneer may give better glue bonds and, all in all, a higher dryer production (Erb, 1974). Any increase in the redry rate, however, means that more floor space is required for storing the veneer to be redried.

The redry rate can be computerized to control the drying time. The dryer operator sets the rate on a computer (at, say, 10 per cent), the computer then automatically counts the sheets to be redried and, if the rate is too high (say, 17 per cent), it slows down the dryer conveyor; conversely, if this rate is too low, the computer accelerates the conveyor.

(b) Dryer Without Continuous Moisture Detector

If a continuous moisture detector is not available, the dry veneer should be checked regularly with a hand-operated moisture meter. When such meters make firm contact on cool veneer and are calibrated for a given species and veneer thickness, they are quite accurate when the veneer ranges from about six to 15 per cent MC. After running the dryer for a time (about the time needed for five rows of sheets), the operator can check the average MC of the dry veneer and adjust the drying time to obtain the MC desired. Again, some of the veneer will be too dry and some too wet.These sheets may cause bonding difficulties at the press. Without a continuous moisture detector which picks up some of the faulty veneer, this type of trouble in the pressing operation should be expected.

An experienced operator can sometimes tell if the veneer is dry just by observing it. When the veneer is being over-dried, static electricity makes the dryer snap, crackle and pop. Over-dried veneer will be hotter to the touch, and darker in colour. Under-dried veneer will be cool to the touch, there will be less noise from static electricity, and the veneer may have less end waviness and buckle. Mill trials conducted by western Forintek staff (Troughton, 1980) at a B.C. plywood plant confirmed much higher surface temperatures, 230°F (110°C), for over-dried veneer (zero per cent MC) and much lower surface temperatures, 145°F (63°C) for under-dried veneer (nine per cent average MC) in a cross-flow veneer dryer. The surface temperatures were measured using a hand-held infrared temperature sensor just before the veneer entered the cooling dryer section.

Continuous moisture detectors and portable moisture meters are useful instruments for the dryer operator since he relies on them to set his drying time. Because these instruments are only as good as their calibration, it is important to check them regularly for accuracy (see Chapter 2, Section 3).

6.5 Setting the Air Speed

Ordinarily, air speed (velocity is set by the dryer manufacturer and, therefore, is not adjustable manually. Should a mill decide that, for whatever reason, the air speed should be increased, by doubling it for instance, it must be repeated that the increase in power required for such an improvement is enormous (to double the volume of air displaced per minute, the fan motors would have to consume eight times more power). The air-flow distribution within the dryer is discussed in Chapter 4, Section 1.

Although air speed is kept constant for all drying conditions, there is one case where the fans can be stopped completely: when very thin veneer (1/85 in. [0.3 mm] or less) is being dried. This veneer dries quite fast in still air, and can be torn easily by air turbulence.

6.6 Setting the Position of the Dampers

The moisture removed from the veneer must escape from the dryer. Veneer dryers are designed so that, with the dampers only slightly open, there is generally still enough space to allow moisture to escape as fast as it is removed from the wood. The statement that the air in a dryer must be dry to dry veneer is simply not true; if veneer were to be dried in a chamber full of saturated steam at 300°F (149°C), its final MC would be around two per cent (see Figure 6). It becomes apparent that the dampers are closed too far only when the dryer smokes around the exhaust or suction area, around the rollers at the exhaust section of a longitudinal dryer, or along the exhaust side of a jet dryer, or when there is too much condensation in the mill.

Smoking around the supply area or along the supply side of a jet dryer indicates only faulty seals or door closers and means that immediate repairs are needed to restore the dryer to proper operating condition. It does not indicate that the dampers are closed too far.

One problem which occasionally shows up when closing the dampers on a gas-fired dryer is the possibility of the flame pulling away from the burner, losing heat output, and even going out completely. This is a problem of gas/air mixture at the point of combustion and is the result of either improper mixture adjustment of the burner system or use of a burner that was not designed for such applications as veneer drying. The higher humidity and lower oxygen content in a tight dryer with the dampers closed is the cause of the problem (Erb, 1974).

By opening the dampers, hot air escapes through the vent stacks; this must, of course, be replaced by fresh air. A study of energy use in dryers conducted on the West Coast (Corder, 1976) has given the following results:

Portion of Total Damper Position	Air Intake (tons/hour)	Thermal Energy Used to Heat Air Escaping Through Stacks (%)	Veneer Moisture Removal Rate (tons of water/hr)
Damper nearly closed	14	24	1.92
Damper largely opened	29	36	1.98

Since these 15 extra tons of air that must be heated with the dampers opened do not improve drying, opening the dampers does little but waste energy.

An automatic damper control was developed which maintains a specific pre-set pressure in the dryer; this system can work only if the dryer has a minimum of air leaks (Franich, 1978).

6.7 REDRYING VENEER

(a) Volume of Redry Veneer

With the present state of technology, it is not possible to economically produce dry veneer with a very even MC. The variability to be expected is indicated in Figure 2 (Chapter 1). In most large mills, a continuous moisture detector marks the sheets that are too wet as they come from the dryer; these sheets must be redried. We have seen in Section 4 of this chapter that, by adjusting the drying time, one can vary the proportion of sheets to be redried (in other terms: the longer the drying time, the smaller the percentage to be redried). Many mills aim at a redry rate of five per cent; however, Figure 12 shows that (in the case illustrated at least) a 15 per cent rate gives more veneer within the desired MC range (Erb, 1974).

Some mills use a simple technique to check the redry rate (Chow, et al., 1973): the total height of the in-going piled veneer is measured and compared with the height of redried veneer over a fixed two- to four-hour period. This is a better method than counting the redried sheets produced during a very short period (say five minutes) since the redry rate may vary considerably from moment to moment; i.e., according to the MC of the logs being peeled.

(b) Strategies for Redrying Veneer.

Plywood mills use different strategies to redry veneer. If some mills have the storage space, they will stack the redry veneer for one or two days to allow some equalization of MC and then pass the veneer through a moisture detector. The veneer that is still too wet to

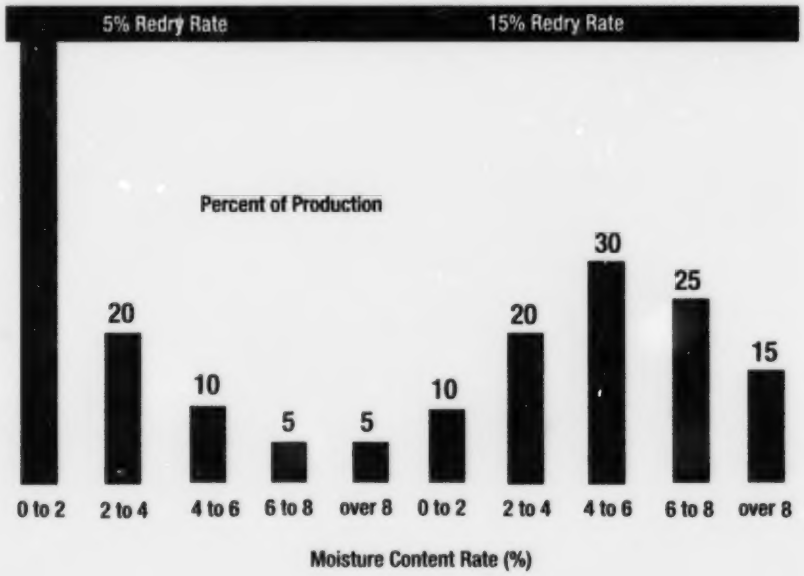


FIGURE 12

The influence of redry rates on moisture content distribution in dry Douglas-fir sapwood veneer. The mill from which these rates were taken wanted an average MC of five per cent and accepted veneer within the MC range of two to eight per cent. A five per cent redry rate gave 60 per cent over-dried veneer, and only 35 percent acceptable sheets. A 15 per cent redry rate gave only 10 per cent over-dried veneer, and 75 per cent acceptable sheets (Erb, 1974).

use can then be passed through the dryer at a fast rate and a low temperature not exceeding 300°F (149°C). Otherwise, the low MC redry veneer will be overdried and surface inactivation will result. Some plywood mills pass all their redry veneer through the dryer using the above conditions.

Another method to redry veneer is radio frequency (RF) (Wilson, 1989). Several U.S. plywood mills have been using this method for many years because of the low electrical rates in the Pacific Northwest. RF heating of the veneer is very effective since the electrical energy goes to the wettest portions of the veneer and therefore the wet pockets receive maximum drying. The temperature inside the bundle of redry veneers heated by RF reaches temperatures well above 212°F (100°C) up to 284°F (140C). After the RF heating, the bundles of dry veneer have to be stored for about four days to allow redistribution of MC and the veneer to cool. Canadian plywood manufacturers have been reluctant to utilize RF technology (Troughton, et al., 1994) because of the large veneer storage areas required, the high electrical consumption, and the capital costs of over $1 million for an RF dryer.

A mill trial on the drying of redry veneer was conducted by Forintek (Troughton, et al., 1994) on an industrial 4- x 8-foot press at a plywood plant in New Westminster, B.C. Redry veneers were selected from normal drier production at the plywood mill and press dried at two sheets per opening for two minutes in a prototype press with modified platens. After press drying, the veneers were stacked for 42 hours to allow them to cool and equalize in MC. Results showed that that initial moisture pockets of 12 to 15 per cent were reduced to approximately seven per cent. Figure 13 shows a typical MC change in a 4- x 8-foot redry veneer sheet after press-drying and stacking. In one trial, five-ply panels made using sap redry veneers as centre plies showed promising results in terms of bond quality.

A 10-opening redry press operating on a three minute production cycle (two sheets per opening, one minute loading/unloading, two minutes redrying) can handle the redry veneer (up to 20 per cent of production) resulting from a conventional dryer. Press drying redry veneer could provide a lower cost processing option for mills in place of capital intensive alternatives such as RF drying. However, although lower in cost overall than the RF technology, the cost of the mechanical handling system to load and unload redry veneer in a 10-opening press has slowed the transfer of this technology into the plywood industry.

During the period 1994–1995, radio frequency/vacuum (RF/V) was evaluated at Forintek Canada Corp. to dry redry and green spruce-pine-subalpine fir (SPF) veneer. Several trials were conducted at The University of British Columbia (UBC) and one industrial trial was conducted at a Vancouver forest products company.

The advantage of applying vacuum during the drying process is that the boiling point of water is greatly reduced below 100°C. Thus RF/V drying offers the advantage of lower drying temperatures, around 50°C, which would lead to higher quality veneer and prevent veneer surface inactivation (Troughton and Chow, 1971) resulting from high temperature drying. By preventing surface inactivation, the veneer will exhibit better bonding properties. Also, the lower temperature of the dried veneer would allow it to be more rapidly used in the plywood manufacturing operation compared to the conventional RF process for redry veneer and therefore substantially reduce the required storage time.

Results from the Forintek study showed the RF/V method using the RF/V technology at that time was not effective in drying veneer to a uniform MC both for green veneer and redry veneer. The resulting variability in MC in the dried veneer would lead to bonding problems during the pressing stage in the plywood manufacture. A further complication with RF/V drying is that there is species effect in that subalpine fir dries faster than spruce which adds to the difficulty of drying the SPF species to a uniform MC. As well, the batch process of the RF/V method is not set up for a high throughput of veneer as is the continuous method used by the veneer dryers in the plywood industry and therefore not practical for drying green veneer.

However, further work has been done by a B.C. company (Heatwave, 2000) to improve the RF/V technology available in 1994–1995. Since 1995, many new improvements have been made by Heatwave to the RF/V technology including more uniform electric fields. Using the new RF/V technology, several trials are being conducted by western plywood companies in 2001 to evaluate this technology for drying redry veneer. Raute Wood Ltd. is also involved in evaluating this technology. According to Raute Wood Ltd., the results for drying redry veneer are showing good potential.

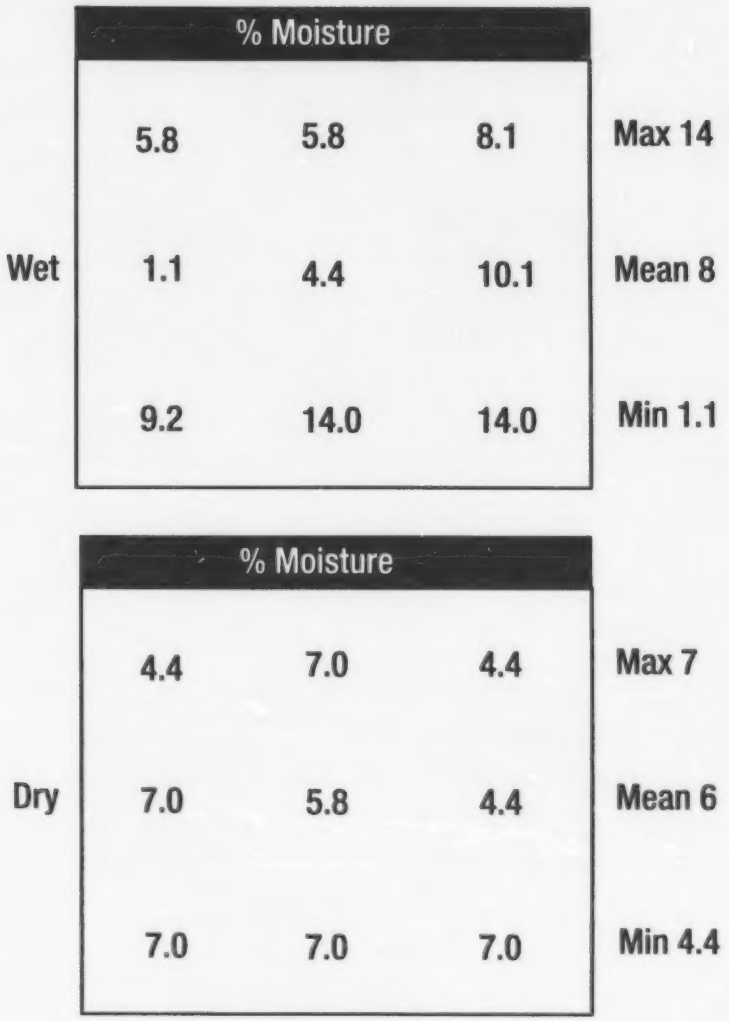


FIGURE 13

Typical moisture change in redry veneer after press-drying and stacking

6.8 COOLING AND STACKING THE VENEER

(a) Cooling

If the veneer is too hot (or too dry) when it reaches the glue spreader, the water in the glue mix evaporates from the glue line too quickly resulting in a dried-out glue line (a condition that gives weak glue bonds). The weak glue bonds occur because the glue does not transfer properly to the adjacent veneer since the glue has now lost its flow properties.

This is one of the reasons why the veneer goes through a cooling zone as soon as it leaves the last drying zone. In the cooling zone, unheated air is blown on the hot veneer. Often, this short cooling period is insufficient and the veneer is piled several hours before going to the glue spreader.

Sliced veneer must also be cooled when it leaves the dryer. If this is not done, the hot upper face of the top sheets dries further, and the veneer tends to curl.

(b) Stacking

The proper technique of offbearing and stacking veneer is also imperative since the veneer is often quite brittle and easily broken. In order to eliminate edge damage and attain firm loads, veneer should be stacked so that the sheets are straight and the edges square. This is of particular importance when handling narrow, random-width sheets since the lack of uniform size can make stacking difficult. The outside edges of these loads should always be kept slightly higher than the middle because this keeps the pressure of any veneer movement towards the centre. Occasional pieces laid diagonally tend to stabilize the load. If the loads are crowned (higher in the middle), the pressure is towards the outside, causing loads to fall apart easily or veneers to shift outward making them vulnerable to damage (Figure 14).

Since some loads of thick veneer are often cut in half as a unit, with a large circular saw or band saw, and used for core stock, extra care must be taken to make straight and square loads. This will eliminate diagonal cut and short core which means less waste or fewer reject panels (Franich, 1978).

6.9 Automatic Control of the Drying Process

The condition of the veneer going into the dryer often changes. It is the dryer tender's job to make the necessary changes in dryer control settings to compensate for wood variables and produce dry veneer with an MC as uniform as possible. As veneer drying exists today, the operation often requires much (if not all) of the attention of the dryer tender. Therefore, a few systems have been developed to control the drying process automatically. Three such systems are outlined below.

(a) Systems based on redry percentage

Two such systems are described in a report from the American Plywood Association (Franich, 1978):

The Microdyne Company has an automatic dryer control which consists of three moisture detectors and a computer—one moisture detector at the green end, one inside at some point and one at the dry end. Data from each is continually fed to the computer and the dryer controlled by an analysis of all conditions. For example, if the dry end detector indicates the redry rate is too low, it would tell the computer to speed up the dryer; but if the internal detector says the veneer is too wet, the dryer may actually slow down since the dry end data is after the fact.

Ward Systems have designed an automatic dryer control (also based on a computer) that should be considered. Control data is taken from the dry end detector and internal temperature at some point in the dryer. The data from the detector is based on the last 32 sheets of veneer checked and is continually updated. The computer is set for the desired redry rate and the veneer being dried. Thus, it counts sheets rather than marks. This unit also has a sap discriminator that will prevent the computer from counting sap sheets marked wet when drying heart. This is a common reason for erroneous redry rates as often much of the redry from the heart loads is actually sap veneer.

Automatic dryer controls should be considered as an aid to increasing dryer production and reducing fuel costs. This is especially important to any mill dependent on natural gas as the prime energy source.

(b) System based on temperature differentials

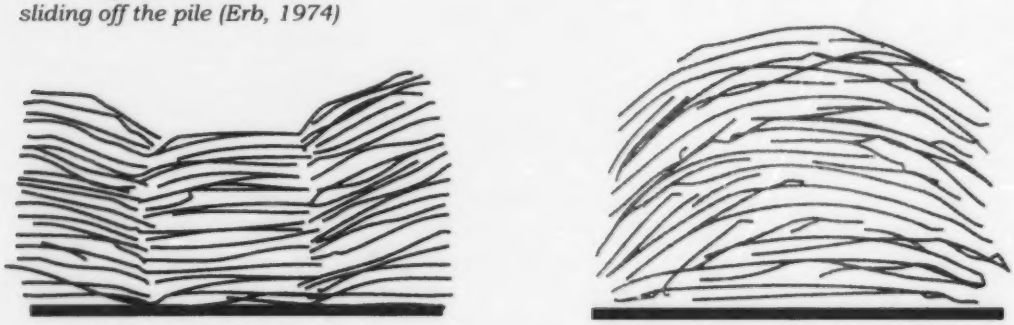
The delta T principle (Robinson, 1987) is based on the premise that as hot air is passed over green veneer, the drop in temperature as the air passes over the veneer, delta T, is proportional to the MC of the veneer. This temperature drop, delta T, is incorporated into a microcomputer-based control system. Deviation of this delta T value from the setpoint supplies a control signal for the dryer speed to either speed up or slow down. The tem-

perature probes T1 and T2 are positioned near the dry end of the dryer. Thus if delta T is higher than the setpoint, the veneer is too wet and the dryer speed is slowed down and vice versa. Thus this control system measures the change in temperature of the hot circulating air across the veneer and uses this variable as a feed-forward signal to control the moisture of the exiting veneer.

According to mill veneer drying evaluations, production increases of from five to 10 per cent were gained along with significant quality improvements when the delta T system was installed in both jet and longitudinal dryers.

FIGURE 14

Veneer Stacking Methods. When stacked correctly the edges are square, the sheets are straight and do not risk sliding off the pile (Erb, 1974)



Correct Method

Incorrect Method

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CHAPTER 7

DRYER MAINTENANCE

For proper maintenance, the dryer and all related equipment must be in good mechanical condition. This means that a good preventative maintenance program is needed that will correct potential problems before they cause any serious trouble. This would include not only the dryer itself, but also the boiler operation, lathe, dryer, feeding and offbearing equipment, and moisture detectors (Erb, 1971).

7.1 MAINTENANCE OF THE DRYER

Maintenance operations (Feihl, 1982) should follow, at the time intervals specified, the steps indicated in the maintenance instruction sheet which comes with every dryer. If this sheet is lost, another one should be ordered from the manufacturer. However, if this is not possible (e.g., if the manufacturer is not in business any more), the following maintenance schedules (one for a cross-flow dryer, the other for a jet dryer) could be used as a guide. Please keep in mind that the schedules outlined below are examples only.

PLANNED MAINTENANCE SCHEDULE FOR A CROSS-FLOW DRYER

Notes:

1. The Moore dryer for which this schedule has been written can be heated either by steam or by gas.

2. Maintenance intervals are based on dryer runningtime (8-hour daily operation) rather than elapsed time, unless otherwise stated.

3. Figures in brackets indicate the number of items to check in a 3-zone dryer.

DAILY

(a) Blow down two instrument air filters daily, regardless of operating condition of dryer.

(b) Standardize and check Bristol recorder battery (this is the drying time recorder).

WEEKLY

(a) Clean dryer.

MONTHLY

(a) Check all safety devices as follows:

i) Main burner flame failure optical scanners. With burners in operation, remove three scanners from mounts and cover with hand. Burners should extinguish and an alarm should sound.

ii) Pilot burner flame failure scanners. Remove three scanners from mounts and cover with hand. Attempt burner ignition; pilot burner flame failure light should stay on and, upon release of pilot burner ignition button, alarm should sound.

iii) Gas pressure switches (3). With burners in operation, close main gas shut-off valve. Burners should be extinguished by the safety circuit before they die from lack of gas, and alarm should sound.

iv) Primary air-pressure switches (3). With burners in operation, shut down primary air fan. Burners should be extinguished by the safety circuit before they die from lack of air, and alarm should sound.

v) Circulating air-flow switches (3). With burners in operation, shut down circulating air fans. Burners should be extinguished and alarm should sound.

vi) Stack damper switches (3). Attempt burner ignition with stack dampers closed. Start of purge cycle should be prevented.

vii) High zone temperature limit switches (3). With burners in operation, manually trip Mercoid switches. Burners should be extinguished and alarm should sound.

(b) Grease cold zone rollers (34 nipples) (see Section 7.2).

(c) Grease roller chain tensioner idler (1 nipple).

(d) Check oil level in roller drive gears and variable speed reducer.

(e) Oil tachometer drive chain.

(f) Grease circulating air fan motors (4 nipples each on hot zone motors, 1 nipple on cold zone motor). Grease lightly.

(g) Check belt tension of circulating air fans (4).

(h) Check physical appearance of burners (3).

(i) Check gap (1/16:), electrodes and insulators on spark plugs (3).

(j) Compare indicated zone temperatures between the recorder and the relevant Mercoid switch.

(k) Clean lenses of flame failure scanners (6) and in-scanner mounts (6).

(l) Oil and grease circulating air fan controllers (3) (one grease cup and two oil cups each).

(m) Check burner gas pressures (3).

(n) Check gas control valve (3) linkage; set screws (6) for tightness.

(o) Check that conveyor rolls are turning normally. Check for worn bearings or broken gear teeth.

TRI-MONTHLY

(a) Oil centre arbor in Bristol recorder (1) (2 drops light machine oil).

(b) Clean contacts in Bristol recorder standardizing unit (1) with wipe paper.

(c) Grease circulating air fan controllers (3) (2 nipples each).

(d) Grease roller drive motor (1 nipple).

SEMI-ANNUALLY

(a) Disconnect linkage and pneumatic air line from gas control valve operators (3) and check for friction in operator's and control valves. Disconnect linkage from bottom socket only, and ensure, when reconnecting, that rod sits solidly in socket.

(b) Clean air valves (3) in gas control valves.

(c) Lubricate gas safety shut-off valves (3) (2 nipples each).

(d) Dismantle, inspect and clean pilot burner solenoid valves (3).

(e) Check operating voltages (3 sets of test jacks) in Fire-eye control cabinet.

(f) Clean slidewire (1) in Bristol recorder.

(g) Clean pilot valves (4) in Moore controllers (2).

YEARLY

(a) Renew diaphragms in steam control valves (5), gas pressure regulators (6), and gas control valve operators (3). This should be done regardless of dryer operating hours.

IT IS UNNECESSARY TO LUBRICATE THE FOLLOWING:

(a) Circulating air fan bearings.

(b) Tachometer magneto.

(c) Primary air blower and motor.

PLANNED MAINTENANCE SCHEDULE FOR A JET DRYER (HALE, 1980)

EVERY SHIFT

(a) Check oil in reservoirs and air unit. Refill as required.

(b) Drain water from traps.

(c) Oil wet end bearing slides (see Section 7.2).

(d) Check for malfunction; noisy operation, etc.:

- i) Tracking system top conveyor
- ii) Tension settings, top and bottom conveyor
- iii) Temperature control
- iv) Damper operation
- v) Fans
- vi) Worm gear housing for excess heating

WEEKLY

(a) Clean out dryer, wet end, dryer box, transition and cooling section.

(b) Grease fans (see Section 7.2):

- i) If drying temperature is below 270°F (132°C), grease once per week for each shift operated
- ii) If drying temperature exceeds 270°F (132°C), grease as often as daily if required
- iii) Bearing manufacturer specifies use of high temperature grease preferably applied while running. Correct application is to stop when grease starts to appear at bearing seal
- iv) Grease drive chains including feeder, main drive and cooler drive
- v) Grease idler sprockets on main drive
- vi) Grease upper and lower shafts in Reeves variable speed drives

MONTHLY

(a) Sweep off top of dryer.

(b) Oil damper bearings.

(c) Grease all pillow blocks:

- i) Feeder pillow blocks
- ii) Idler sprockets, wet end (zerks on hubs)
- iii) Main conveyor shaft bearings
- iv) Cooler pillow blocks (including remote fittings on lower idler shaft)

(d) Check oil level in speed reducer.

(e) During overall inspection, check all parts for security or evidence of wear.

(f) Inspect graphite bearings in feeder, return rolls and cooling section

(g) Check operation of tracking device and oilers.

ANNUALLY

(a) Remove and inspect jets; clean when necessary. (This may be required more often in extremely dusty conditions or where pitch from softwoods is encountered.) Repair any deformed jets.

(b) Change oil in speed reducer.

(c) Replace neoprene diaphragms in steam valves (if used).

(d) Inspect conveyor for excessive wear, including tracks, chain, mesh, and rollers; straighten bent parts.

Note: The above checklist is based on actual experience, coupled with a constant program of discussion of maintenance techniques with suppliers. Neglect of this minimum list of simple maintenance procedures will result in greatly increased downtime and shortened life of components subject to wear, as well as lowered production.

7.2 LUBRICATION

Here again the following lubricants and recommendations are given as examples for those mills who have lost their veneer dryer operating manual.

a) Conveyor
If the dryer is to be operated at temperatures of 400°F (204°C) or above, the hot-zone rollers and roller drive chain should not be lubricated. If the dryer is to be operated consistently under 400°F (204°C), lubricate the hot-zone rollers monthly and the drive chain continually in accordance with instructions. Use Shell Clavis No. 41 oil.

At temperatures of up to 300°F (149°C), any good, stable oil, approximately SAE 30, will be suitable if properly applied. Hydraulic fluid is often used, sometimes mixed about 4:1 with STP (special treated petroleum).

b) Fan bearings
Any good NLG1 No. 2 grease is suitable but it should be checked for compatibility with originally supplied grease. Note: We particularly recommend Dow Corning No. 44 Silicone grease provided that the bearings are originally packed with it. It is not compatible with any other grease. If use is to be discontinued, all bearings be replaced.

c) Ball bearing pillow blocks and needle bearings
Any good NLG1 No. 1 grease is adequate. Note: Use an entirely different gun from that used for fan bearings to avoid mixing.

(d) Graphite bearings
Lubricate only when they squeal. Use kerosene or plain water. Do not use a machine oil.

(e) Worm gear reducer
Use No. 90 worm gear oil. Replace after the first 100 hours of operation.

7.3 MAINTENANCE OF RELATED EQUIPMENT

An even steam pressure applied to steam-heated dryers is essential; a dryer cannot operate efficiently if the plant has a sloppy boiler operation. Equally important is strict thickness control at the lathe. A variation of 0.02 inch (0.5 mm) in a 0.100 inch (2.5 mm) veneer sheet results in a difference of 20 per cent in the drying time. This means that a careless peeling operation will cause a false redry rate and produce too much over-dried veneer with a loss in total dryer production (Erb, 1971).

Finally, calibration and maintenance of moisture meters and continuous moisture detectors is most important. Advice on this subject is given in Chapter 2, Section 3.

7.4 REFERENCES

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CHAPTER 8 FIRES AND PLUG-UPS

8.1 FIRES

Wood debris, pitch or veneer can sometimes catch on fire inside the dryer. When this happens, fire is detected by the smoke escaping from the machine or by the charred pieces of wood coming out of the dryer, or both.

A report, (Bramhall, 1967), on dryer fires in softwood plywood operations is summarized in the following pages. This report is based on information received from technical personnel representing western plywood companies. Although fires are less frequent in hardwood veneer dryers, some of the corrective measures and fire-fighting methods described below can still be useful in hardwood veneer mills.

(a) Critical high temperatures

At about 430°F (220°C), wood catches fire if there is a flame to start it. This is the ignition temperature.

At about 520°F (270°C), pine and spruce continue to burn by themselves once a fire has started. This is the combustion temperature.

At about 560 °F (290°C), pine and spruce catch fire by themselves (without a flame to start it.) This is the self-ignition temperature.

Note: Pine resin can catch fire spontaneously at 175°F (80°C) if left at this temperature for about two hours.

(b) Causes of fire

A fire can take place only if there is some combustible material, an adequate supply of oxygen (air), and the material is at or above its ignition temperature.

The veneer itself is not usually the combustible material concerned. It is seldom burned in dryer fires, partly because of its high ignition temperature (430°F/(220°C) and partly because of its temperature being considerably lower than that of the dryer. Pitch that has condensed on the walls of dryers is the primary fire source.

(c) Pitch build-up

Observations by some dryer operators indicate that the pitch will not condense on dryer walls if their temperature is above 275 °F (135°C). This explains why the hot (dry) end of the longitudinal dryer does not have a pitch build-up and, consequently, has no fires. The green end is considerably cooler, however, because of the intake of wet veneer, pitch condenses on the green-end walls and constitutes a fire hazard.

Pitch also condenses on dryer doors that do not fit tightly. Towards the dry end of many longitudinal dryers, there is a slight pressure within the dryer generated by the circulating fan. However, as the gases pass toward the green end, the pressure gradually decreases until it is below atmospheric pressure. The result is that, while leaky doors are recognized at the dry end because of the escape of smoke, they cannot be seen at the green end with the draft in the other direction. Yet it is the entry of air, not the escape of smoke, that presents the greatest hazard.

The possibility of pitch build-up is greatly increased when dryers are operated at low temperatures. Despite the good intentions of some fire-prevention officers, their recommendations to reduce dryer temperatures in order to reduce fires have the opposite effects. Some mills have purchased oversized, highly efficient dryers to handle peak loads. Under normal operation, however, their full capacity is not required. The dryers are, therefore, frequently operated at low temperatures to reduce their capacity.

In some cases, water is injected into a dryer as a fog to reduce the fire hazard. The local cooling caused by the evaporation results in pitch condensation.

(d) Air intake

More than half of all dryer fires occur when the dryer is full of air. These include fires that begin immediately after start-up, repeat fires, and fires that occur when the dryer is kept only patially filled with veneer. Under these conditions, less than the normal amount of water evaprates from the veneer, the steam content of the dryer is reduced, and its oxygen content increased.

As seen in Chapter 3, air is not necessary for drying. Any hot gas, including superheated steam, will be equally effective. The reduction of the amount of air taken into the dryer will reduce the oxygen concentration to the point where it will not support combustion, even if combustible materials are present. The entry of cold air, which is now reduced, will not cool the dryer walls and doors to permit condensation of pitch.

(e) Preventive measures

These consist of cleaning operations and special operating methods.

1. Cleaning

Dryers should be cleaned weekly to remove pitch deposits and slivers. The most common methods of cleaning the dryers are scraping and blowing the dryer's debris and pitch with an air hose and washing the dryer with a caustic solution. While the second method results in considerable saving in labour, it requires extra care in two respects; frequently,

the caustic solution does not reach all pitch deposits, and, if the solution is not properly washed from the dryer, ignition of the salt when the dryer is returned to service is a distinct possibility.

2. Special operating methods

To eliminate the air in the dryer, particularly at start-up, one company has installed a 1.5 inch steam line that carries 150 pounds of steam into the dryer, and the air is flushed out before the veneer is fed in. This operation requires only a few minutes.

There is no disadvantage to leaving the steam on throughout the weekly operation. Certainly, during periods of slow dryer feeding, after maintenance, or when the dryer has been stopped for any reason, flushing with steam will reduce the possibility of fire.

Some fires can be attributed to the excessive heating of slivers lying on steam coils after the weekly clean-up. To prevent this, the fans should be turned on before steam is admitted to the heating coils.

The setting of the exhaust-stack damper poses a problem for which every operator has his own preference. As a rule, the more open the damper, the more gas escapes and the more air will be sucked in. Since air is not necessary for drying and constitutes a fire hazard, the only gas that should go up the stack should be that which evaporates from the wood. No air should be admitted to the body of the dryer. The dampers should be closed as much as possible until excess smoke or moist air leaks into the mill. This operation will not affect the efficiency of drying.

To reduce air leaks, the doors of the dryer should be well sealed. A high-temperature silicone stripping placed around the doors has been found successful for this purpose. In conjunction with this, all surfaces of the dryer should be well insulated to prevent cold spots resulting from heat leaks. The booster fan of longitudinal dryers should be moved so that the superheaters are on its supply side. This, with the sealing of the doors, will increase the dryer pressure and will decrease or prevent the suction of cold air (hence, the deposit of pitch), at the green end.

(f) Fire suppression

At the present time, when fire starts in a dryer, the fans are shut down and at times, the doors are opened. No advantage is gained from this action when the veneer is not on fire. One company, using a gas-fired longitudinal dryer set for 380° F (193°C) at the dry end and 330°F (160°C) at the green end, (temperatures sufficiently high to eliminate pitch build-up), merely floods the floor of the dryer with water to catch burning debris and continues operation. This approach is commendable, but could be improved by installing a high-pressure steam line to purge the air from the system.

Avoid using water sprinklers inside the dryer since rapid cooling of the metal causes serious distortion of rollers, frame members, walls and doors.

8.2 PLUG-UPS

It could happen that, instead of moving smoothly through the dryer, veneer sheets get stopped and form a massive plug-up. A plugged dryer is costly: veneer, labour and drying time are wasted and a dryer fire could result.

Some common causes of plug-ups are outlined below:

1. The top sheets of a pile of green veneer start to dry and curl up. When fed to the dryer, their raised corners can hit a roll. Corrective measure: keep the top sheet wet.

2. Fish tails (sheets produced from logs not fully rounded) are fed with the thin edge first which may bend and hit a roll. Corrective measure: always feed the clipped edge first.

3. Sheets are fed too close to the roll ends and may hit a roll gear. Corrective measure: paint a ring on the feed rolls to mark the safe limit.

4. Some rolls are distorted, (sometimes following a dryer fire), and rotate unevenly, pushing the veneer against the next roll or toward one side. Corrective measure: straighten or replace roll.

5. A tooth of a roll gear is broken; this gear stops turning and the chain may jump over several roll gears. One or several rolls stop turning (dead rolls) and cause a plug-up. Corrective measure: replace damaged gear.

6. Heavy pitch build-up on the rolls. Corrective measure: let the dryer cool down and scrape off the pitch that has hardened.

Note: To unclog the dryer, one mill uses an air-operated saw mounted on the end of a 10-foot handle which can reach the width of the dryer from either side.

8.3 Summary

1. Dryer fires are caused by the presence of combustible material, primarily pitch, and by the presence of air in a dryer.

2. Pitch will deposit on the surfaces which are colder than about 275°F (135°C). If all parts of the dryer are above this temperature, no deposit will occur, and the possibility of fire will be greatly reduced.

3. Air leaking into a dryer is the most common cause of cold spots which lead to build-up of pitch deposits. The tight sealing of all doors and other openings, using a high-temperature silicone gasket material where possible, will reduce cold spots.

4. The oxygen content of the dryer can be reduced by the same techniques which eliminates cold spots. In addition, the purging of air from the dryer by steam injection after every shut-down will reduce fires significantly.

5. Good clean-up procedures, either by caustic solutions and flushing or by scraping and air-blowing, will generally reduce dryer fires.

8.4 Reference

Bramhall, G. 1967. Cause and prevention of veneer dryer fires. Forintek Canada Corp. Report VPX20. Vancouver, BC. 11 pp.

CHAPTER 9

VENEER INCISING STRATEGIES FOR DRYING

9.1 DRYING BENEFITS

Veneer incising technology developed at Forintek (Troughton, et. al., 1987; Troughton et. al., 1989) used in front of the veneer dryer was evaluated at Forintek's Western Laboratory and at Forintek's member plywood mills. This technology was shown to decrease drying time by three to 15 per cent depending on wood species, and substantially reduce "blows" (delamination) during the pressing of plywood. Another advantage of veneer incising is that the veneers are flatter and therefore, handling on automated plywood lay-up lines is improved. Further, the incising of the veneers greatly improves the preservative treatability of the plywood.

Recently, modifications (Dai, et. al., 1998) have been made to the roller bar on the lathe to allow veneer incising at the lathe. This new Forintek technology has been licenced to Premier Gear and the majority of Forintek member plywood mills are now using it. Not only does this new incising technology provide the previous benefits for the incisor in front of the veneer dryer, but also provides the following additional benefits: fewer spin-outs and less curl-up for the veneer near the core (especially spruce), and higher veneer yields.

9.2 DRYING STRATEGIES FOR PRESSING

Another veneer incising drying strategy that can be used for the plywood or LVL pressing stage is to dry incised veneer to a uniform high MC, for example, 14 per cent MC. These veneers would be used as the outermost veneers in thick plywood or laminated veneer lumber (LVL) products and low MC (three per cent MC) veneers would be used in the core. Work conducted at the Westerm Laboratory showed this self-generated steam method (Troughton, 1998) would require close control of the MC in the high MC veneers since a change of two per cent average MC in the outermost veneers had a substantial effect on the pressing time of 13-ply incised SPF LVL (Table 4). This method allows for the generation of steam in situ and the steam produced by the outside veneers is driven towards the centre of the panel resulting in faster heat transfer compared to conventional platen heating. Using this self-generated steam method, production can be increased by more than 30 per cent and result in substantially increased profits for plywood and LVL plants.

With the present drying technology, since it is difficult to produce uniform high MC veneers, a second veneer incising drying strategy that can be used for the plywood or LVL pressing stage is a steam-injection method. (Troughton et. al., 2000) developed by Forintek and demonstrated in pilot plant trials. This new processing technology requires incised veneer (average MC of three per cent) to facilitate the movement of saturated steam through the veneers and reduce blows during the pressing cycle. Using this steam-injection technology, production can also be increased by more than 30 per cent and provide similar benefits as the self-generated steam method.

TABLE 4

Pressing Times for 13-ply Incised SPF LVL

Veneer Moisture Content Layup	Time to reach 105° (min)	Reduction in Pressing Time (%)
Control (all 13 veneers @ 3% avg MC	22.50	0.0
4 outermost veneers @ 10% avg MC 9 core veneers @ 3% avg MC	19.50	13.0
4 outermost veneers @ 12 % avg MC 9 core veneers @ 3% avg MC	18.00	20.0
4 outermost veneers @ 14% avg MC 9 core veneers @ 3% avg MC	15.50	31.1

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CHAPTER 10

VENEER DEFECTS CAUSED BY DRYING

Defects in dry veneer fall roughly into three categories: nonuniform final MC; buckling, splitting, loose knots; and surface modification. This chapter will briefly examine the causes of these defects and suggest corrective measures where practical.

10.1 NONUNIFORM FINAL MOISTURE CONTENT

Improper sorting of green veneer will lead to a wide variation of MC in each sort. Further, some veneer sheets, especially those containing sapwood and heartwood (Chapter 1) can vary considerably in MC within the same sheet. Moreover, the drying temperature of a dryer may vary considerably from one conveyor deck to another and from side to side. As a result, veneer dried to the average target MC needed for the panel pressing stage can still show wide variations (e.g., for an average MC of five per cent, it could range from zero to 12 per cent [Figure 2]).

The MC of the dry veneer should be checked on a regular basis using portable moisture sensors (Chapter 2) which are frequently calibrated by the oven-dry method, the most accurate method to measure MC.

The following strategies can be used to produce more uniform MC in dry veneer:

1. Sorting the green veneer accurately into MC groups such as heartwood, mixture of sapwood and heartwood, and sapwood and drying these sorts using a proper drying schedule (Chapter 6).

2. Establishing a good method and schedule to dry/redry veneer (Chapter 6).

10.2 BUCKLING, SPLITTING, LOOSE KNOTS

These defects are listed together because they have one main cause in common—uneven wood shrinkage. Shrinkage of wood occurs only when the MC drops below the fibre saturation point (about 25 to 30 per cent). Shrinkage increases linearly as the MC approaches zero per cent. Tensions in the wood result when some areas of a veneer sheet dry sooner than others. These tensions may be strong enough to buckle or even split the veneer.

Buckles and splits are more likely to occur in logs that have been allowed to dry partially while in storage (drying mainly at the ends and in the vicinity of deep checks). Some logs also contain growth stresses that may distort the wood once it is sawn, rotary cut or sliced.

In some trees, the presence of an abnormal type of wood, called reaction wood, often produces veneer that will buckle and split. Reaction wood is generally found in trees that are leaning or pushed by a prevailing wind in one direction. In softwoods, a section through such a tree shows areas with dark annual rings.

Contrary to normal wood, reaction wood shrinks along the grain, therefore, when both types of wood are present in veneer, tensions are created which buckle and split the sheet (Figure 15).

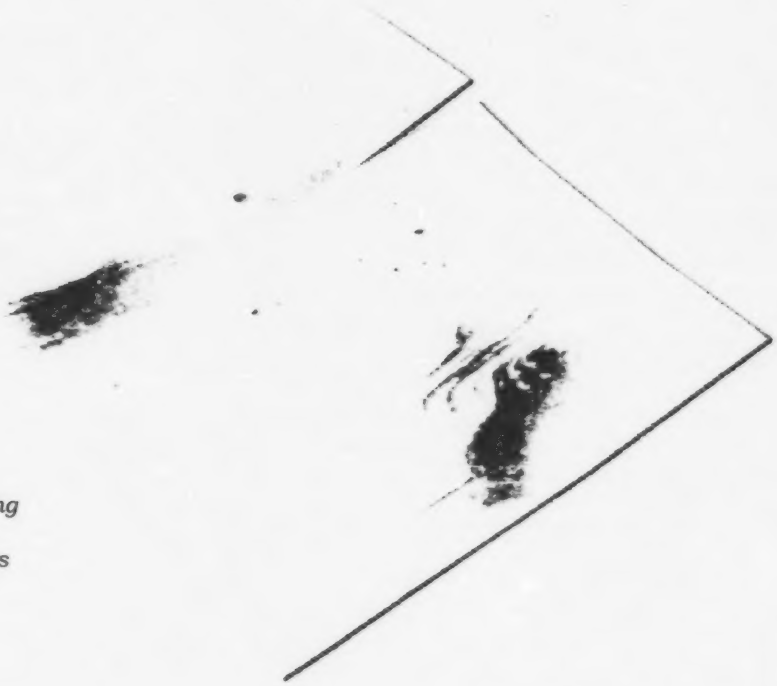

FIGURE 15

White spruce veneer sheet containing reaction wood (dark areas) which caused drying defects such as splits and buckling

End buckling (Figure 16) occurs when the edges of a sheet dry faster than the centre and are not held flat with sufficient force during drying. It can also result from drying veneer peeled from logs, the ends of which were allowed to dry before being peeled. End buckling can be minimized by overlapping the sheet ends by one-quarter to one-half inch (six to 12 millimetres) during drying whenever practicable. In high-performance jet dryers, end buckling is mostly eliminated.

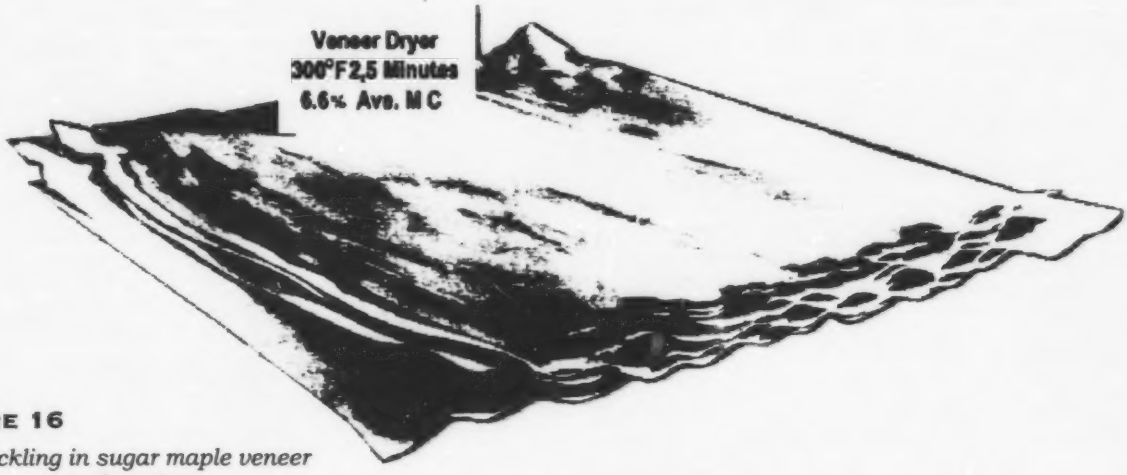

FIGURE 16

End buckling in sugar maple veneer dried in a cross-flow dryer

Buckling can also be caused by faulty rotary-cutting techniques (Figure 17). If the horizontal opening between the knife and pressure bar of a lathe is narrower at the centre of the log than near the ends, the veneer comes from the lathe with buckles in the centre. If the horizontal opening is wider towards the centre of the log, the opposite develops and the veneer comes from the lathe with a tendency to end buckle (Feihl, 1982).

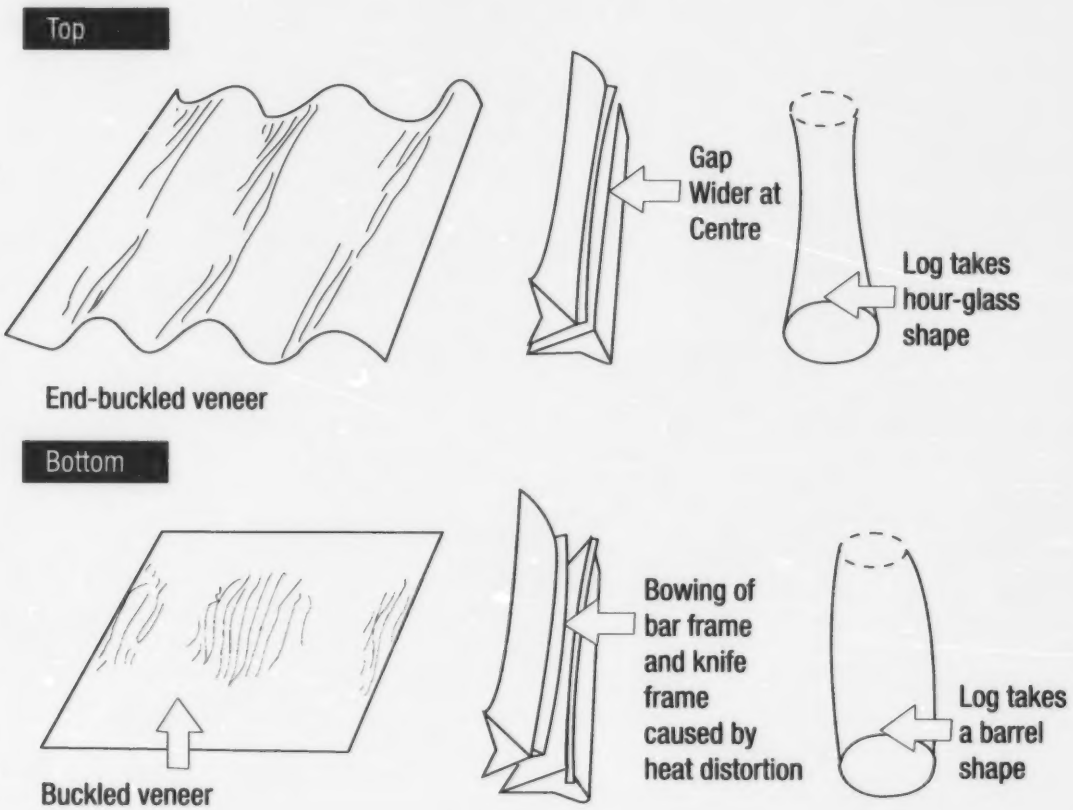

FIGURE 17

Top:
Green veneer buckling caused by faulty lathe settings (irregular opening between knife and bar)

Bottom:
Centre bucking is often caused by heat distortion of the lathe carriage when peeling hot logs

When face veneers (particularly sliced sheets) are excessively buckled, they can be flattened in a specially-designed press at 240° F (116°C). The press is about 60 by 120 inches (1.5 by three metres) and has several openings. Each platen is loaded with bunches of five to 10 sheets, the press closes for a few seconds with a pressure of 150 psi (7.18 kPa), re-opens automatically to let the veneer breathe its steam and repeats the cycle twice. The total time trials have shown that this method is more effective for flattening short waves than it is for long waves (Lutz et al., 1974).

Finally, to reduce buckling all veneer should be cooled and held flat as it comes from the dryer. Cool veneer is less likely to buckle and will not contribute to pre-cure of glue lines. The dried veneer should be neatly stacked on flat skids and the top of the pile weighted. Flitches of sliced veneer should promptly be strapped in flat crates.

Shrinkage is also partially responsible for knots coming loose during drying and falling in the dryer, at the glue spreader or while plywood is being assembled. Drying studies of softwood and hardwood veneers conducted at Forintek (Dokken, 1972; 1975) indicated that the handling of veneer loosens about as many knots as drying does.

10.3 Surface Modifications

These modifications include surface inactivation, pitch spread and iron stain. In general, of these modifications, surface inactivation causes the biggest problem.

(a) Surface Inactivation

As was discussed in Chapter 3, for most of the drying process the temperature of the veneer being dried is much lower than that of the dryer. However, when the veneer MC approaches zero per cent in the dry zone of the dryer, typically around 360° F (182°C), surface inactivation will begin and color development is initiated. It is the accurate measurement of this color change that can be used to control veneer overdrying and hence, surface inactivation. Under severe drying conditions, the veneer becomes very dark in color resulting in scorching–severe surface inactivation (Feihl, 1982).

The color change is measured quantitatively using a reflectance colorimeter (spectrophometer) (Chow, et al., 1973). Measurement is made by placing the head (Figure 18) of the instrument perpendicular to the grain direction of a sheet of veneer and then marking the outline of the head on the veneer surface. The initial color reading is recorded and the veneer is passed through a dryer. When the veneer sheet comes out of the dryer, the head is placed in exactly the same position as before and the color change between the initial and final reading noted. Several measurements (about 40) should be made on 10 randomly selected veneer sheets (four readings per sheet) to obtain a representative average value. The amount of color change to cause surface inactivation, and thus, poor wood failure and strength, varies among tree species. As examples of the use of this instrument in a laboratory, an average color intensity difference of greater than 15 for Douglas-fir and four for white spruce indicates surface inactivation levels have been exceeded and bond quality levels will be marginal.

This method represents a good quality-control tool for a plywood mill to establish drying schedules that produce minimal surface inactivation.

A second method to measure the degree of surface inactivation is the water-drop absorption test–a method recommended by the Amercian Plywood Association (Erb, 1971). Although this method is not as quantitative as the colorimeter test method, it is easier to apply in the plywood mill. In the water-drop absorption test, an area of flat grain veneer is selected and marked for identification. One small area is scraped and another is not. One drop of water is placed on each area. The total time for the water to be absorbed into the wood is noted.

1. Observation of the scraped area

   If the water is absorbed into the scraped area in 15 minutes or less, this time is ignored. If the absorption time is greater than 15 minutes, there is some factor other than surface inactivation involved and the test will not be valid.

2. Observation of the unscraped area

   When testing softwood species, if the drop of water on the unscraped area is absorbed in 30 minutes or less, gluing problems from surface inactivation will range from none to

FIGURE 18

Photograph showing the measurement of reflectance intensity from a veneer surface

slight. If the water has noticeably spread out but some still remains on the veneer surface after 40 minutes, gluing problems from surface inactivation are quite likely to occur. If the water drop on the unscraped area is standing much as it was originally with no spreading at the end of 40 minutes, gluing problems from surface inactivation are certain to occur.

The seriousness of the problem will depend on the percentage of specimens that fall in each category. If, for example, 100 specimens were tested and only a few showed severe surface inactivation based on the above interpretation, gluing problems would be minor. If, on the other hand, 80 or 90 of the 100 specimens showed severe surface inactivation, serious gluing problems could be expected and immediate corrections in drying procedures would be indcated.

Since the water drop test indicates the condition of the veneer surface when the sheets leave the dryer, it is necessary to select the samples at the dryer. If samples are taken out of a mill for testing in the laboratory, they should be wrapped carefully in plastic to prevent any changes in MC between sampling and testing.

Surface Inactivation can be controlled by:

1. Using proper drying schedules for each sort of green veneer checked by the colorimeter method including using relatively low temperatures, 360° F (180° C) in the dry zone, (i.e., in the second half of the dryer).

2. Not using redry rates below 10 per cent. This seems to keep the veneer-surface temperature below the point at which surface inactivation becomes a problem in most cases, (Franich, 1978).

3. By using the borax method (Chow, 1975). This method consists of spraying a one percent solution (weight/volume) of sodium tetraborate pentahydrate (borax: $Na_2B_4O_7{\cdot}5H_2O$) on the green veneer. The borax helps prevent the chemical reactions that cause surface inactivation during drying. For quality-control purposes, it is very important to accurately control the amount of borax solution sprayed onto the veneer surface since high-borax concentrations on the veneer surface will result in poor plywood bond quality. The borax will also contribute to pollution abatement (Troughton and Chow, 1976) by reducing blue haze above veneer dryers (Chapter 11). The borax solution is not corrosive and will not damage the dryer. Borax is a low-cost chemical which would facilitate using the borax method in a plywood mill on an economic basis.

b) Pitch spread

When resinous species are dried at high temperatures, 450°F (232°C) or more, the pitch concentrated in knots and in pitch pockets melts and soaks into the surrounding area (Figure 19). This pitch spread affects the bond quality when urea formaldehyde adhesives are used; however, phenolic glues are less affected. Pitch is also known to bleed through thin hardwood faces and cause finishing problems.

c) Iron stain

Iron stain (iron tannate) develops when iron dissolved in water comes into contact with tannin in veneer; iron-stained veneer becomes blue-black (Figure 20). The species most affected by iron stain are oak and chestnut and, to a lesser degree, beech, yellow and white birch, maple and walnut.

Iron stain can occur during drying if the drying temperature is low (less than 275°F/135°C) or if the dryer conveyor is not made of stainless alloy, a metal highly recommended for oak, chestnut, walnut and butternut. Iron stain increases with pressure from the conveyor, therefore, it is important that the conveyor parts in contact with the veneer are kept smooth and in good shape.

Iron stain also occurs if water containing dissolved iron drips on the veneer (e.g., water from a leaky pipe or leaky roof).

To remove iron stain from oak, chestnut, walnut or butternut, the following method is recommended: wash the stained area with a solution of two ounces (60 g) of oxalic acid in one pint (0.5 L) of water. Use only enough solution to remove the stain (excess acid may leave a pink color), and wash away excess oxalic acid with water. Oxalic acid is poisonous if swallowed and may irritate skin so wear rubber gloves and wash hands immediately after using the solution.

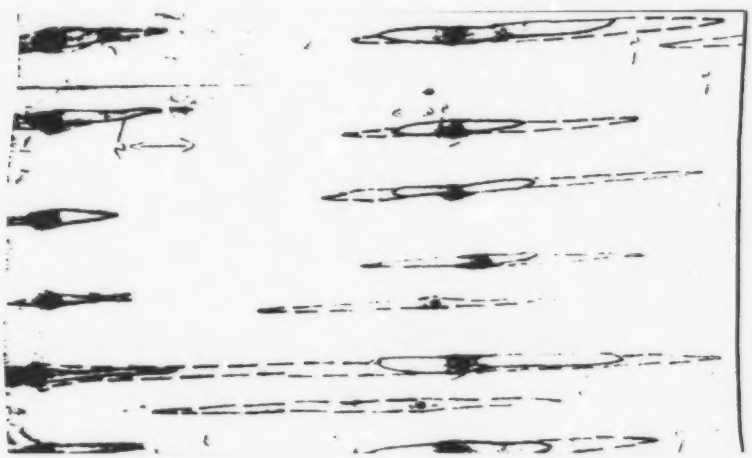

FIGURE 19

Pitch spread in red pine veneer dried at 450°F

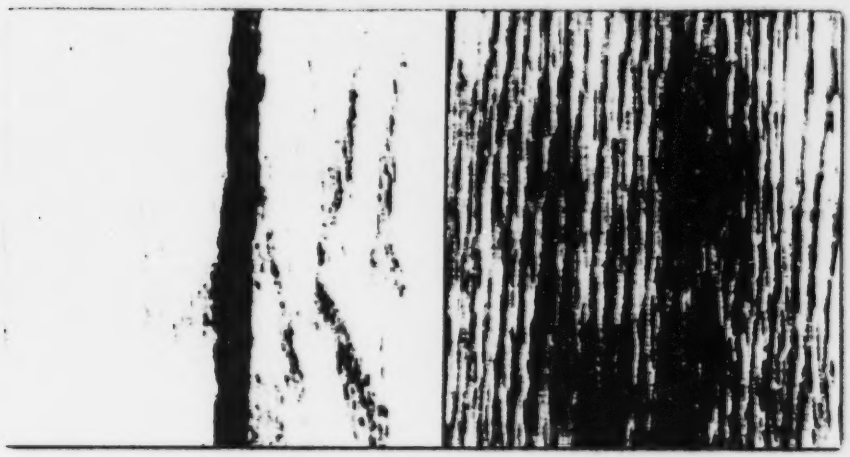

FIGURE 20

Iron stains on oak veneer
Left: Stain caused by contact with steel bar
Right: Stain caused by water dripping (the water contained some iron in solution)

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CHAPTER 11 ENVIRONMENTAL ISSUES - POLLUTION ABATEMENT TECHNOLOGIES

11.1 ENVIRONMENTAL REGULATIONS

In the early days of the industry, environmental issues (Technology Roadmap, 1998) represented a very small component of any decision to build and operate a plywood plant. However, in today's highly sensitive environmental climate, these issues have come to represent a significant initial and operating investment by the owner. In some cases, environmental issues can make or break a project. Environmental permitting has become one of the single greatest challenges facing the industry this decade, and it will continue to pose a challenge as environmental regulations become more stringent in the future. It is therefore, extremely important that all stakeholders in the industry understand these challenges and the existing and future remedial solutions available.

Compliance with environmental standards requires a complete organizational commitment. Environmental pollution abatement equipment has become as important as any other plant process equipment and must be treated as such to ensure that long-term compliance is maintained. Failure to comply with regulations can result in costly litigation, fines or even the closure of the plant. Any case of environmental noncompliance, regardless of how small, can irreparably damage a company's reputation and make permitting very difficult at the existing plant or for future plants.

Ambient air quality limits are based on the contaminant's time-averaged concentration in ambient air at ground level. Table 5 contains information on ambient air quality criteria in different provinces. The point of impingement limit is calculated using atmospheric dispersion algorithms to predict the theoretical maximum ground level concentration. Point of impingement limits are used only by Newfoundland and Ontario.

Stack emission limits are usually determined on a case-by-case basis and based on the type of control technology used. Stack emission limits are controlled in a company's operating permit. Ambient air quality limits are typically contained in the province's environment act/regulation, but may also be added to a company's permit for a particular substance if deemed necessary.

TABLE 5 *Provincial Ambient Air Quality Criteria on a 24 Hour Averaging Period (µg/m³)*

	NS	NB	PEI	NFLD	Quebec	MUC[1]	Ontario	Manitoba (Guidelines)	SK	AB	BC
Carbon Monoxide (1 hour)	34 600		35 600	5 000	34 000	35 000	36 000	35 000	15 000	15 000	
Formaldehyde (1 hour)				65	37 (15 min)	12	65				60 (action level)
Hydrogen Sulphide	8	5	5	30 (1 h)	14 (1 h)	5	30 (1 h)	5	5	4	
Nitrogen Dioxide	400(1h)	200	900(1 h)	400(1 h)	207		200	200	400(1 h)	200	
Sulphur Dioxide	300	300	300		288	260	275	300	150	150	160
Total Suspended Particulate	120	120	120	80 (1 h)	150		120	120	120	100	150
PM10											50

1. Montreal Urban Community
Source: NGM International, 1998

11.2 DRYER EMISSIONS

The veneer drying process produces a wide range of pollutants in the form of nitrogen oxides, carbon monoxide, particulate, formaldehyde and wood extractives (volatile organic compounds [VOCs]). The quantity of these pollutants will vary depending on the source and type of wood used, dryer temperature and production speed.

The amount of wood extractives emitted during drying can have an imporant effect on the blue haze found above veneer dryers. Several mechanisms are postulated to cause blue haze. As the wood extractives are emitted from the hot dryer exhaust stacks and contact the colder ambient air, the higher molecular-weight extractives condense and form liquid droplets, resulting in a fine aerosol. The second mechanism postulated to cause blue haze above veneer dryers is the interaction of the volatile wood extractives, especially olefinic compounds with ozone.

Previous research at Forintek (Troughton and Chow, 1976) showed that low concentrations of borax were effective in improving plywood-bond quality (Chow, 1975) and reducing the loss of wood extractives from softwood veneer during drying. It was postulated that the reasons for the effectiveness of borax in reducing the volatility of the wood extractives was twofold: salt formation and chelation with the wood extractives. The borax solution should be applied at a level of 0.16 g borax per square foot of veneer. Levels higher than this amount are detrimental to plywood-bond quality and hence, it is very important to provide the correct application level. Based on this work, treatment of veneers with borax would contribute toward pollution abatement by reducing blue haze above veneer dryers and improving plywood-bond quality.

Because of the high moisture content in the flue gas and the resinous nature of VOCs, fouling of control pollution abatement equipment is a continuing source of trouble.

11.3 POLLUTION ABATEMENT TECHNOLOGIES

Some pollution abatement technologies have been around for many years while some have only recently come to the forefront with the advent of more stringent environmental regulations. Table 6 pro-

TABLE 6 *Emission Control Technology Summary*

	Removal Capabilities					VOCs			Process Experience			Typical Costs	
	SO_2	NO_x	CO	PM	PM10	VOC	HCOH	Phenols	Vendor Availability (3 or more)	Commercial Operation	Demo	Capital $/MSF	Operating Cost
Primary & Secondary Cyclones				E	F				Yes	Yes		0.75	L
Wet Cyclones				E	G	P	P	P	Yes	Yes		1	L
Dry ESP				E	E	P	P	P	Yes	Yes		4	M
Baghouses				E	G	P	P	P	Yes	Yes		3	L
WESP				E	G	G	G	G	Yes	Yes		4.5	M
Electrostatic Filter Beds				E	G	G	G	G	No	Yes		5	M
RTO			G	F	F	E	E	E	Yes	Yes		6	H
RCO			G	F	F	E	E	E	Yes		Yes	6.5	H
Bio-filtration				G	G	G	G	G	No		Yes	5.5	L
Scrubbers	E	P	P	G	F	F	F	F	Yes	Yes		3	M

L = Low H = High F = Fair
M = Medium E = Excellent P = Poor

Source: NGM International, 1998

vides an overview as to the application of those technologies for the reduction or removal of the various emissions found in veneer dryers as well as typical costs. These technologies are now discussed.

11.3.1 PRIMARY AND SECONDARY CYCLONES

Cyclone technology has been around for many years. Primary and secondary cyclones have been used on dryer outlets to separate the dried wood product from the air stream and then remove any residual particulate from the air stream prior to discharging to the stack. Cyclones are also commonly used on dust collection systems where particulate is the only emission. These devices are very efficient for particulate collection but they have no capability of reducing NO_x SO_2, CO or VOC emissions. Therefore, in today's environmental climate, cyclones are usually not sufficient and they must be paired with additional environmental equipment to provide the required reductions in emissions.

11.3.2 WET DUST COLLECTORS

Wet dust collectors are very similar in nature to the dry cyclones except that water is added to assist in the capture of the dust particles. The centrifugal action of the collector removes the water and dust particle. These collectors are very efficient at collecting particulate and they will capture some condensable hydrocarbons. These collectors, however, may be troublesome in colder climates, and they result in additional waste water which must be treated.

11.3.3 DRY ELECTROSTATIC PRECIPITATORS (ESP)

ESPs are generally considered particulate control devices. Typical ESPs use an electrified wire to charge the particles, which are then attracted to the collection plates. A rapper system is used to dislodge the collected particulate from the collection plates. ESPs provide high particulate collection efficiencies and will collect VOCs in their aerosol form. However, because of the resinous nature of the particulate and VOCs in the dryer gas, ESP collection plates will foul quickly and cause a shutdown of the collector for cleaning. As a result, they are not normally used on dryer exhaust gases. They are commonly used to control emissions on heat energy systems where no VOCs are present and the particulate and gases are in a dry state.

11.3.4 BAGHOUSES

Used interchangeably with dry ESPs, baghouses provide for removal of particulate matter only. They are commonly used to remove particulate where no VOCs are present. Gas is passed across a series of nomex bags which collect the particulate matter. A reverse air or pulse air system removes the particulate from the bags. Baghouses provide a lower operating cost option than dry ESPs, however, they are not as effective at removing small particulate. This is because particulate size removal in baghouses is limited by the size of openings in the bag media, while ESPs impart electrical charges to all particles. Again, as was the case for ESPs, baghouses are not used on moist and resinous dryer gases because of fouling and blinding of the bags. They are used on dry gas only. Filter bags must be replaced periodically.

11.3.5 WET ELECTROSTATIC PRECIPITATORS (WESP)

WESPS have been used successfully in recent years on dryer outlets to control particulate matter and condensable hydrocarbons (VOCs).

The WESP uses a high-intensity ionization electrode to attract the charged particles. Water is used as a quench medium to saturate and entrain the condensable hydrocarbons as well as to flush the collection area. WESPs are efficient collectors of particulate and condensable VOCs. As previously discussed, the majority of VOCs are condensed into a fine aerosol and therefore can be efficiently collected by electrostatic means. WESPs, however, require additional water treatment and can be troublesome in more northern climates.

WESPs and electrostatic filter beds (see below) will continue as leading technologies for dryer emission controls in the industry. Recent developments such as the E-tube from GeoEnergy will continue WESP dominance of the market. This system involves a refinement of the WESP technology in that the ionization electrode configuration is a suspended mast with disc electrodes within a collection tube. This results in an intense electrostatic field that is up to two times higher than conventional wire-in-tube arrangements, hence, a higher particulate collection efficiency and a smaller precipitator.

11.3.6 ELECTROSTATIC FILTER BEDS (EFB)

EFBs are more commonly referred to as Electrostatic Gravel Filters. EFBs are a proven technology in the removal of particulate and condensable VOCs. Specifically designed for difficult-to-clean dryer exhaust gases, EFBs employ a proprietary technology to remove particulate and condensable VOCs. Developed by MIT scientists in the 1970s, EFBs have become commonplace in the reconstituted wood industry.

Electrostatic gravel filters employ an electrostatic principle to impart a charge to the gravel bed which collects the particulate and the aerosol VOCs. The gravel is continually removed from the bed and cleaned of the collected pollutants. The cleaned gravel is returned to the bed and the pollutants are captured in dry form in a collector for disposal. The EFB achieves a high collection efficiency by virtue of the tremendous collection surface area available in the gravel bed. Because of the dry nature of the process and the specialized gravel cleaning process, fouling of the collector is seldom a problem. This technology is a completely dry system which makes it widely suitable for cold climates. More than a dozen systems have been installed in Canada on dryers and thermal oil heaters and they perform very well.

11.3.7 REGENERATIVE THERMAL OXIDATION (RTO)

RTO technology has been around for many years but has only recently been adapted to meet the needs of the wood industry. RTOs have recently been installed on dryer outlets to destroy VOCs, CO and organic particulate. RTOs rely on thermal oxidization to destroy these emissions. The dryer or press gases are sent to the RTO where the VOCs, CO and organic particulate are incinerated at temperatures of about 800°C (1,500°F). To increase the thermal efficiency of the system, ceramic beds are used to preheat the inlet air prior to combustion. This technology is very effective in the destruction of VOCs, CO and organic particulate. However, RTOs are ineffective at removing inorganic particulate and do generate some NO_x from the combustion of natural gas to generate the required temperatures. RTOs are fairly expensive to operate and require a source of fossil fuel. Inorganic particulate may cause bed fouling. The RTO operates at, or close to, the melting point of some of these inorganic particulate. Once melted, these by-products can permanently adhere to the ceramic bed and cause premature bed failure. Occasional bed burn-out is required to clear the bed of inorganic particulate and reduce pressure drops. Additional inorganic particulate devices may be required upstream of the RTO.

Future RTO systems will be equipped with novel features to reduce plugging by inorganic particulate. Their combustion system will also be improved so that NO_x emissions may be reduced. Concentrators are likely to be used to reduce the volume of conveying air from the contaminated air stream.

11.3.8 REGENERATIVE CATALYTIC OXIDATION (RCO)

RCOs are similar in nature to RTOs except that a catalyst is employed to oxidize the VOCs. They operate at a lower temperature (300-400°C/ 570-750°F), thus providing operational savings by burning less natural gas. Destruction efficiency is similar to that of RTO systems, but they produce less NO_x because of the reduced natural gas consumption. The catalyst will however lose its effectiveness over time. Higher maintenance cost and high-replacement cost of the catalyst may offset any savings over the conventional RTO technology. Additional inorganic particulate control upstream of the RCO may also be required to meet emission requirements and prevent ceramic bed fouling. To date, only three RCOs are known to be operating in the U.S. and none in Canada.

11.3.9 SELECTIVE CATALYTIC REDUCTION (SCR)

The selective catalytic reduction system is designed to destroy nitrogen oxide (NO_x) in a variety of process treams. SCR is highly effective and can eliminate up to 95 per cent of nitrogen oxides present. The catalyst used to convert the NO_x into nitrogen and water is specifically designed to operate at temperatures between 290 and 590°C (550 and 1,100°F).

11.3.10 BIO-FILTRATION

Bio-filtration is a recent technology used for the capture and destruction of particulate and VOCs. Typically better suited for controlling press emission, bio-filtration offers an alternative to RTOs and RCOs. Mesophilic micro-organisms are well suited for the destruction of easily degradable VOCs such as formaldehyde, phenols, urea, methanol, ethanol as well as pinenes, limoenes, camphene, MDI and ketones. Bio-filtration technology does not require natural gas to pyrolize the VOCs, therefore, offering a substantial saving over RTOs and RCOs. Since no natural gas is burnt, bio-filtration does not contribute to NO_x emissions.

Exhaust gases from the dryer are sent to the bio-filtration unit where water is sprayed into the gas for cooling to remove particulate. This gas is then passed through filter beds which house the micro-organisms. The degradation process is aerobic and complete. End products are carbon dioxide, water, mineral salts and biomass. A number of different filter beds have been tested such as wood bark, shavings and chips. The filter of choice appears to be activated carbon. Though more expensive, it provides for longer bed life without compaction. Bed temperatures need to be kept fairly constant for greatest efficiency and to prevent harm to the micro-organisms. The system requires a fairly large area for the beds.

A number of pilot tests have been carried out for this type of technology. Ongoing development of this technology will result in greater acceptance due to improvements in efficiency and reliability.

11.3.11 ROTARY CONCENTRATOR ADSORPTION (RCA)

The RCA uses rotating adsorption zeolite or activated carbon beds to trap the VOCs before venting the clean air into the atmosphere. This system increases the fuel value of VOC-laden gas streams and the fuel economy of the oxidizer by raising the concentration of VOCs in the inlet gases. Savings vary based on the nature of the emission flow and operating conditions.

11.3.12 CLOSED LOOP GASIFICATION

Closed loop systems are typically directed at the drying process for most plants. They generally re-circulate dryer exhaust air back to the heat energy system to be used as combustion make-up air thus combusting the VOCs and particulate, and controlling emissions. Two types of such systems have recently been installed; closed loop gasification and closed steam loop systems.

The closed steam loop system is currently being offered by Swiss Combi as the EcoDry system. Wood dust, oil or gas is burnt in the heat energy system, a gas-to-gas heat exchanger transfers energy to the dryer gas stream. This closed loop gas stream is re-circulated around from the dryer to the heat exchanger. About one-third of the dryer air stream is bled off and used as combustion air in the heat energy system. Here the VOCs and particulate captured in the dryer are burnt off at high temperature.

Closed loop gasification is a system offered by Callidus Technologies. Originally employed for the incineration of hazardous waste and sludge, the system burns wood waste in a reduced oxygen atmosphere in a dryer. Exhaust gases from the kiln pass to a secondary combustion chamber (SCC) where additional air is provided to complete combustion. The gases then flow through a gas-air heat exchanger, thermal oil coil, baghouse and then exhaust into the stack. Fresh air is heated in the gas-air heat exchanger and sent to the rotary drum dryers. The hot air returning from the dryers, now containing VOCs and particulate, is then sent to the inlet of the dryer and the SCC as make-up combustion air. This completes the closed loop cycle. Because of the temperatures and the travel times in the SCC and the dryer, the organic particulate and VOCs are completely incinerated.

With this closed loop combustion process, the exhaust gas stream passing to the baghouse contains only inorganic particulate.

11.3.13 SCRUBBERS

Scrubbers have been employed in a number of industries to control SO_2 emissions, condensable hydrocarbons and particulate. When SO_2 capture is required a reagent is typically used in the process. Dryer exhaust air flows through a water spray tower. Here the gas is cooled to adiabatic saturation which permits condensation of hydrocarbons. Particulate are captured by the fine water molecules in the scrubber sprays. Water falls to the bottom of the scrubber where it is re-circulated to the sprays. A small bleed stream is drawn off the sump to remove the condensed hydrocarbons and particulate. A mist eliminator section prevents water vapour carry-over out of the scrubber and up the stack. Depending on the location of the plant, the stack gases may need to be re-heated to reduce plume opacity and prevent plume inversions. Scrubbers are efficient removers of particulate and, to some degree, condensable hydrocarbons. However, condensed hydrocarbons tend to be in the form of a very fine aerosol making capture in the scrubber quite difficult. Scrubbers have been mostly replaced recently by WESPs or EFBs which capture these fine condensable compounds with greater efficiency. Scrubbers require additional water treatment and may require frost protection in colder climates.

11.4 REFERENCES

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